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(54) METHOD FOR PRODUCING A WATER-FUEL EMULSION AND A COMPOSITE MULTICOMPONENT FUEL

(57) The invention deals with making hydrocarbon fuel used as process fuel at industrial facilities, in particular thermal power plants, metallurgical works, chemical plants and other high heat and power consumption facilities. The invention can be used for making fuel from moist mazut fuel oils, furnace oils, oil-slimes, heavy residual oil fractions, as well as coal tar oils and resins with simultaneous utilization of bottom water polluted with hydrocarbons.

The technical result of using the invention is a simpler method of making high-quality fuel-water emulsion and multicomponent composite fuel from hydrocarbon inputs - mazut fuel oil, furnace oils, oil-slimes, heavy residual oil fractions, as well as coal tar oils and resins with simultaneous utilization of bottom water polluted with hydrocarbons - without adding gaseous hydrocarbons, which makes the method more effective.

Such a result is achieved thanks to the following: the invented method of making a fuel-water emulsion and multicomponent composite fuel uses heating of the hydrocarbon input with the water content of up to 50 wt % to the temperature of 120°C, processing it with pressure, and cavitation-processing it to make a fine-particle fuel-water emulsion with 0.5 - 5.0 micrometer water particles to subsequently burst hydrocarbon shells with steam for the second-phase fuel spray.

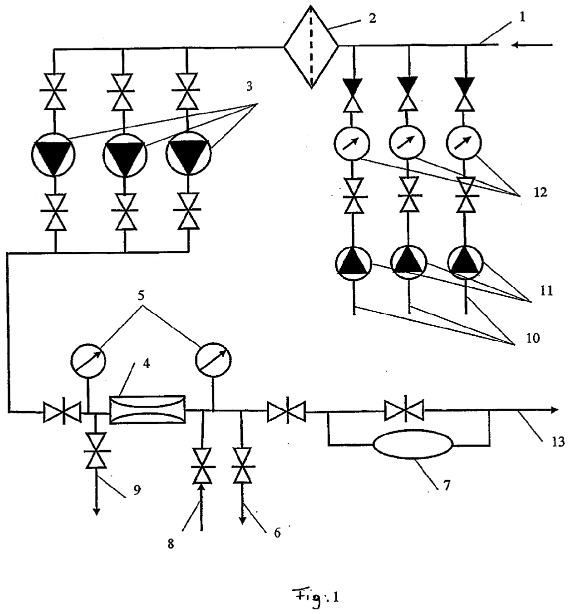

Fig. 1

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Description

[0001] The invention deals with making hydrocarbon fuel used as process fuel at industrial facilities, in particular thermal power plants, metallurgical works, chemical plants and other high heat and power consumption facilities. The invention can be used for making fuel from moist mazut fuel oils, furnace oils, oil-slimes, heavy residual oil fractions, as well as coal tar oils and resins with simultaneous utilization of bottom water polluted with hydrocarbons.

[0002] There is a known method of making gaseous fuel oil for steel-smelting furnaces. It uses replacing part of the injected fuel oil with water to make fuel oil-water emulsion, delivery of inflammable gas - for example, natural gas - with this fuel oil-water emulsion, fan and compressor air, and industrial oxygen to the burner, and then combusting the inflammable components in the flame and taking the combustion products away. The fuel oil-water emulsion is made by sending mazut fuel oil and water to a rotary device for hydroacoustic treatment of liquids. The device has a rotor with a bearing disk and a covering one, and a peripheral ring wall with a number of outlets. Between the ring wall and the solid coaxial wall of the stator there is a resonance chamber connected to a collection chamber. The content of water in the oil-water emulsion is regulated through temperature and flame emissivity providing they stay at least the same as the temperature and flame emissivity for straight mazut fuel oil combustion. The viscosity of the fuel oil-water emulsion decreases depending on the content of water in it, which is controlled by increasing the temperature of the fuel oil-water emulsion at the entrance to the burner providing it stays at least the same as the viscosity of mazut fuel oil when it is used straight (Patent of the Russian Federation № 2253798, class F 23 C 1/00, 2005).

[0003] The disadvantage of this method is the necessity to add inflammable gas - for example, natural gas - and industrial oxygen, which complicates the process.

[0004] There is a known method of making fuel emulsion and multicomponent composite fuel from mazut fuel oil. Heated M100 and/or M40 mazut fuel oil and stabilized gas condensate are mixed in a certain proportion: 50°C hot fuel oil and 20°C hot stabilized gas condensate are sent to a mixing chamber at a pressure of up to 3 atm. Then the mixture is delivered to an emulsifying device where it is treated with ultrasound to make a fine-particle emulsion. Two or more counter currents of this fine-particle emulsion, the temperature of which is kept to be 50-60°C, are mixed in an intense mixing chamber under pressure, and then the ready-made product is sent to accumulator tanks united in a circulation system, where it is circulated at a pressure of 2 atm and moves through the emulsifying device (Patent of the Russian Federation № 2278149, class C 10 L 1/04, 2006).

[0005] This method, used to make fuel emulsion and multicomponent composite fuel from mazut fuel oil and stabilized gas condensate, cannot be used to make fuel from black oil. The method is not effective and affordable enough; the process of making fuel through it is still complex and requires high cost and labor. The necessity to use stabilized gas condensate narrows the area of technological application of the method, since it can be used only at the facilities where gas condensate is available.

[0006] The object of the invention is to develop a method of making hydrocarbon fuel from moist black oil that forms during oil processing, which will allow reductions in cost and labor, and make the technology more affordable.

[0007] The technical result of using the invention is a simpler method of making high-quality fuel-water emulsion and multicomponent composite fuel from hydrocarbon inputs - mazut fuel oil, furnace oils, oil-slimes, heavy residual oil fractions, as well as coal tar oils and resins with simultaneous utilization of bottom water polluted with hydrocarbons - without adding gaseous hydrocarbons, which makes the method more effective.

[0008] Such a result is achieved thanks to the following: the invented method of making fuel-water emulsion and multicomponent composite fuel uses heating of the hydrocarbon input, with a water content of up to 50 wt %m to the temperature of 120°C, processing it with pressure, and cavitation-processing it to make a fine-particle fuel-water emulsion with 0.5 - 5.0 micrometer water particles to subsequently burst hydrocarbon shells with steam for the second-phase fuel spray.

[0009] The method offered allows the production of high-quality fuel from hydrocarbon inputs - mazut fuel oil, furnace oils, oil-slimes, heavy residual oil fractions, as well as coal tar oils, resins and bottom water polluted with hydrocarbons. The quality of such a fuel is much better than that of the mazut fuel oils used. The product emulsion forming the multicomponent composite fuel stays stable for over 12 months, because the dispersion of water and mazut fuel oil in this case occurs at the pre-molecular level.

[0010] The size of 0.5 - 5.0 micrometers for the water particles is optimum: with this size the surface tension force is sufficient to maintain the stable dispersion of the product for a long time. Besides, this size allows the necessary fuel spray rate. If the size of water particles is less than 0.5 micrometers, the steam they produce during combustion of fuel-water emulsion is not forceful enough to burst the hydrocarbon shells for the second-phase fuel spray. If the size is over 5.0 micrometers, the required stability and combustion efficiency cannot be obtained.

[0011] The use of the fuel-water emulsion made through the method offered will allow an increase in the boiler equipment operating times between repairs by up to 40%, and a considerable reduction in pollutant emissions in industrial areas by up to 80% and by an order of magnitude for some indicators. Besides, the water polluted with hydrocarbons is recycled completely, and up to 30% of expensive hydrocarbon fuel is saved.

[0012] In today's operation of boiler units and industrial furnaces using mazut fuel oil and furnace oil the operating personnel face a number of problems that affect the performance of the heating equipment, cause excessive consumption of the fuel, worsen the technical and economic efficiency and quality of the products, and lead to environmental pollution (air pollution with emissions, and soil and water pollution with waste containing hydrocarbons).

[0013] The most common problems occurring when mazut fuel oil is used are the following:

1. *Water in mazut fuel oil.* When mazut fuel oil is unloaded, shipped, stored and kept as a reserve, it absorbs water. Water inclusions in modem "heavy" mazut fuel oils do not practically settle, and it is impossible to remove them by traditional methods. Water in the form of lenses or pockets spreads throughout the fuel oil irregularly, which considerably worsens its combustion quality.
2. *Lower quality of primary mazut fuel oil.* Because of the change in the oil processing technology for the purpose of obtaining larger quantity of light fractions, the quality of mazut fuel oil worsens - its viscosity increases and its flash point rises. Using viscous and heavy mazut fuel oils presents serious difficulties when they are stored and sprayed for combustion.
3. *Mazut fuel oil "ageing".* When mazut fuel oil is stored for a long time using the technology of keeping it as a hot reserve, the light fractions evaporate from it, which leads to an increase in its viscosity and a rise in its flash point. As a rule, such mazut fuel oil after 2 - 3 years of storage, is impossible to combust, and it has to be replaced with "fresher" fuel oil.
4. *Worn-out equipment and insufficient technological level of fuel combustion units.* In some units the technological capacity of mazut fuel oil preparation systems does not allow heating mazut fuel oil to the necessary combustion temperature of not less than 90°C, so the necessary fuel spray rate cannot be reached. It leads to considerable undercombustion and carbon loss (soot), excessive delivery of air for combustion, and so to a decrease in the efficiency of the equipment and excessive consumption of the fuel.
5. *Low-temperature sulfuric-acid corrosion of the metal parts of exhaust ducts.*
6. *Environmental pollution with mazut fuel oil combustion products (carbon monoxides, sulfur oxides, nitrogen oxides, soot, and benzapyrene) and effluent with petrochemical waste.*

[0014] One of the most effective and cheap ways of solving these problems is to modify heavy mazut fuel oils and other oil refinery products to obtain a homogeneous fuel-water emulsion for combustion in boiler and process furnaces. A certain dispersion of such an emulsion, determining the effectiveness of its use, is a substantial requirement. It is the size of water particles in the fuel. The best results are achieved with water particles of 0.5 - 5.0 micrometers in size.

[0015] In the method offered the hydrocarbon input goes through a disperser and then undergoes a cavitation process, which results in regular distribution of water in the form of 0.5 - 5.0 micrometer particles throughout the whole mass, thus forming a highly stable and finely dispersed, homogeneous fuel-water emulsion. The prior heating of the hydrocarbon input to the temperature of 50 - 120°C and the pressure of 50 atm allow obtaining an emulsion with such a size of water particles.

[0016] The invention is explained with drawings.. Fig. 1 is a diagram of making water fuel emulsion, with the disperser used to process the hydrocarbon input; Fig. 2 is a micro-photograph of the primary moist mazut fuel oil; Fig. 3 is a micro-photograph of the fuel-water emulsion obtained from mazut fuel oil; Fig. 4 is a chart showing the nitric oxide content in the flue gas, depending on the steam demand of the boiler unit - for conventional mazut fuel oil combustion (I) and fuel-water emulsion combustion (II); Fig. 5 is a chart showing the sulfurous anhydride content in the flue gas, depending on the steam demand - for conventional mazut fuel oil combustion (I) and fuel-water emulsion combustion (II); Fig. 6 is a chart showing the specific consumption of fuel per 1 Gcal with optimum excess of air, depending on the steam demand - for conventional mazut fuel oil combustion (I) and fuel-water emulsion combustion (II); Fig. 7 is a chart showing the nitric oxide content in the flue gas after the steam superheater with a 1.4 air excess factor, depending on the steam demand - for conventional mazut fuel oil combustion (I) and fuel-water emulsion combustion (II); Fig. 8 is a chart showing the sulfur dioxide content in the flue gas with a 1.4 air excess factor, depending on the stcam demand - for conventional mazut fuel oil combustion (I) and fuel-water emulsion combustion (II).

[0017] The system of making fuel-water emulsion consists of an intake line 1 to take the hydrocarbon input into the system from containers (not shown), filters 2, delivery pumps of the necessary specifications 3, an emulsifying device 4, manometers to help control the operability and fouling rate of the emulsifying device 5, a sampling device to help control the quality of the product 6, an inline moisture meter 7, a steam delivering pipe 8 to clean the emulsifying device 4, a pipe 9 to discharge condensate and sediments from the emulsifying device 4, a line 10 to deliver additional components, such as water or used petrochemical products, pumps 11 to deliver the additional components, measuring devices 12 to help control the quantity of the additional components, and pipes 13 to release the ready-made product.

[0018] The method is as follows:

Example 1. Mazut fuel oil with 50% of water is heated to the temperature of 120°C and is delivered by pumps 3 along line 1 through filters 2 to emulsifying device 4 - a disperser, for example - at a pressure of 30 atm. The pressure in the system is checked with the help of manometers 5. The speed of the flow is 8 - 15 m/s. At this speed and under high pressure the flow of the input substance accelerates and is broken up with the help of a cavitation mesh (not shown) in the emulsifying device. When the flow is being broken up and decelerated by the plates of the mesh, a change of pressure occurs, which produces cavitation bubbles; bursts of the bubbles create shock waves, which additionally destroy the molecules of heavy hydrocarbons and water particles. This process results in the formation of a finely dispersed fuel-water emulsion with 0.5 - 5.0 micrometer water particles.

[0019] Intense cavitation processing of fuel makes structural changes in it: long hydrocarbon chains break up; the fuel becomes "lighter" and its thermal and rheological properties improve; the solid inclusions in it are destroyed and broken up finely. This is confirmed by the positive results of converting boilers and kilns, designed for the combustion of diesel and light furnace oil, to the use of low-grade dark furnace fuel.

[0020] In order to check the quality of the ready-made product, samples are taken with the help of sampling device 6. The ready-made product is received from release pipes 13. In order to clean the system, steam is used; it is sent through pipe 8, and the condensate and dirt is discharged through pipe 9.

[0021] The process of combustion of such a fuel-water emulsion and multicomponent composite fuel is different from the combustion of conventional fuel. The micron water droplets in solvate shells of hydrocarbon fuel vaporize in a highly heated furnace at an explosion rate; the vapor bursts the shells - and the process of the second-phase fuel spray occurs. As a result of this a large number of micro-droplets form from an initial droplet; their evaporation speed is much higher, and the total area of their chemical reaction with the delivered blast air is much greater. Thanks to this, the time of the oxidation reactions (complete combustion) shortens considerably, and so does the amount of the air delivered for the combustion, which lessens the flue gas heat loss and considerably reduces the polluting emissions. Besides, thanks to the high stability of the obtained fuel-water emulsions, the technology does not require settlement and discharge of tank water, which is an important factor in the reduction in environmental pollution.

[0022] The method ensures reliable operation of boilers and process furnaces with up to 50% of water in the initial fuel and provides high energy and ecological characteristics with the combustion of the obtained emulsion in normal mode.

[0023] The comparative tests were carried out with the use of the boiler TΓM - 84 at loads of 260, 290 and 320 t/h and at a temperature of the mazut fuel oil of 110-114°C and of the fuel-water emulsion of 90-95°C.

[0024] The analysis of the flue gas contents was made by a gas analyzer of the type; it was at same time duplicated by a KΓA-M type instrument after the boiler (mode point) and before the exhausters (balance point). The samples of the flue gas were taken with gas probes. The tests lasted 40 - 60 minutes. The criteria used to determine stability of a new mode were constancy of the steam flow, steam pressure in the pipeline, temperature of the flue gas and analysis of the flue gas contents.

[0025] During the tests the boiler was fed with M-40 mazut fuel oil and the fuel-water emulsion (modified mazut fuel oil) made from this mazut fuel oil. The specifications of the fuel are showed in the table.

[0026] The steam consumption was determined with the help of a panel flow meter. The boiler fuel consumption was determined through the net heating value method (minimum heat value method) [*used in the USSR and Russia]* with "gross" efficiency of the boiler being actual, the pressure changes of the fuel delivered to the burners, and the readings of the panel flow meter. The boiler water chemistry was checked through feed and boiler water tests conducted by the chemical lab workers of the station.

[0027] The temperature of the feed water delivered to the boiler economizer during the tests was 207 - 211°C (design value: 230°C).

[0028] The fuel consumption changes were made as to its pressure before the burners. The negative pressure in the boiler furnace was maintained at a constant level of (-1.5/-2.0) kgs/m^2 with the guide vanes of the exhausters. The consumption of the air delivered to the furnace was monitored by its pressure before the burners. The air consumption was controlled by the guide vanes of the blow fans with the gates completely open before the burners.

[0029] Stable combustion without pulsations was set to be optimum. The optimum excess air ratio in the flue gas was determined by the following equation:

$$\alpha_{\text{opt}} = \alpha_{\text{cr}} + (0.03\text{-н}0.04)$$

where α_{cr}, is the critical excess air ratio.

[0030] After the excess air ratio had been determined, tests were carried out to find the data that is necessary for calculation of the heat loss through the flue gas, incomplete chemical combustion and into the environment, and of the gross efficiency of the boiler.

[0031] During the comparative tests the concentration levels of harmful substances in the flue gas (carbon monoxide, nitrogen oxides and sulfur dioxide) were measured where the samples for the analysis of the flue gas contents were taken.

Carbon Monoxide (CO)

[0032] During the tests the fuel in the boiler furnace combustcd practically completely. In the optimum air excess mode the concentration of incomplete fuel combustion products (CO) in the flue gas is not over 50 mg/m^3, which equals 0.01% (while 0.5% is permissible) of incomplete chemical combustion heat loss with the actual air excess.

Nitrogen Oxides (NOx)

[0033] During the tests the concentration of nitrogen oxides in the flue gas was given particular attention, since their toxic properties and harmful effects on humans are among the most hazardous. Usually, nitrogen oxide and nitrogen dioxide are added, to register the emission ($NO+NO_2=NO_x$).

[0034] The tests with 1.0% moisture content mazut fuel oil and 16% moisture content emulsion showed that the combustion of the latter results in a reduction in the concentration of nitrogen oxides in the fluc gas with a 1.4 air excess. Fig. 7 shows the 1.4 air excess concentration of nitrogen oxides in the flue gas for mazut fuel oil (chart I) and the fuel-water emulsion (chart II)

Sulfur Dioxide (SO_2)

[0035] Fig. 8 shows the sulfur dioxide concentration in the flue gas with a 1.4 air excess factor depending on the steam demand for conventional mazut fuel oil combustion (I) and for fuel-water emulsion combustion (II). When the fuel-water emulsion is used, the concentration of SO_2 in the flue gas decreases.

[0036] The use of the fuel-water emulsion results in reduction in electric power consumption (for draft and blast). The indicative calculation of the cost efficiency of the method is the following:

Electric Power for Draft and Blasting

[0037] The results of the experimental data processing showed that for the same loads the use of the obtained emulsion reduces the consumption of electric power for fans and exhausters by an average of 200 kWh.

[0038] With the average boiler operation time of 2,160 hours a year, the use of the emulsion will effect the following electric power saving:

$$\Delta E = 200\ \text{kWh}\ 2160\ \text{h/year} = 432{,}000\ \text{kWh/year.}$$

[0039] The heat saving thanks to the reduction in the fuel heating from 120°C (mazut fuel oil) to 95 °C (fuel-water emulsion) is the following:

The average reduction in the steam consumption for heating the emulsion as against heating mazut fuel oil was 1.16 t/h, with the steam of the following properties: 10 κgs/cm^2 and 250°C. Therefore the enthalpy of the steam was í= 703.2 kcal/kg.

[0040] The temperature of the condensate at the exit from the heaters was 90°C; the enthalpy of water was í = 90.1 kcal/kg.

[0041] The difference of the enthalpies was the following:

$$\Delta í = 703.2 - 90.1 = 613.1\ \text{kcal/kg.}$$

[0042] The saving of heat a year will be

$$\Delta Q = (613.1 \cdot 1.18 \cdot 2160) / 1000 = 1562.67\ \text{Gcal/year.}$$

[0043] The average reduction of the input mazut fuel oil when the fuel-water emulsion was used for combustion was 300 kg/h under the average loads (250 - 270 t/h).

[0044] The saving of mazut fuel oil a year will be

$$\Delta B_M = 0.3 \cdot 2160 = 648 \text{ t/year.}$$

[0045] This calculation shows the cost efficiency of the use of the obtained fuel-water emulsion thanks to decreasing the heating temperature to 95 °C.

[0046] The fuel-water emulsion obtained through the method offered ensures effective operation of the burners when it is heated to 65 - 75°C. In this case the steam consumption will be even lower, which will additionally save heat.

[0047] The ash content of the emulsion obtained through the method offered is reduced from 0.095 to 0.021%, the weight percent of sulfur is reduced from 2.3 to 1.5 %, the combustion value is increased from 9,688 kcal/kg to 10,656 kcal/kg.

[0048] Example 2. The technology is the same as in Example 1, but the input substance in this case is furnace oil with 20% of bottom water. This moist furnace oil is heated to the temperature of 60° C and cavitated at a pressure of 20 atm.

[0049] The combustion of the obtained fuel-water emulsion results in reduction in the emission of toxic substances, such as sulfur and nitrogen oxides, as it is showed by the charts in Fig. 4 - 8.

[0050] With little water in the input fuel, the cavitation process can be performed at a pressure of 6 - 10 atm, which also allows obtaining high-quality emulsion.

[0051] Example 3. In order to determine the changes in the properties of the input mazut fuel oil, during the process of making the fuel-water emulsion, laboratory tests were conducted on samples of the input mazut fuel oil M-100, input mazut fuel oil processed in the emulsifying device, input mazut fuel oil with 22% of water added in the laboratory - without cavitation, and the fuel-water emulsion MM-100 with 19 and 32 wt % of water after the cavitation process. The results of the tests are showed in Table 1.

[0052] The laboratory calorimetric tests conducted to determine the highest and lowest calorific value of the above fuels showed that cavitating the input mazut fuel oil and highly moist emulsion MM-100 results in a considerable increase in their calorific values (converted to dry fuel one) to the lowest combustion value from 42,811 kJ/kg of "dry" mazut fuel oil after cavitation to 58,505 kJ/kg of fuel-water emulsion with 19% of water and 47,090 kJ/kg of fuel-water emulsion with 32% of water. These results are the grounds for recommending the obtained fuel for combustion.

[0053] Example 4. Table 2 shows the properties of the input mazut fuel oil M-40 with 1 wt % of water and fuel-water emulsion with 15 wt % of water. The tests on the emulsion with a high water content (15%) confirm that it has a higher combustion value (43,372 kJ/kg) as against low-moisture-content mazut fuel oil (41674 kJ/kg) with standard water content.

[0054] The above data are the grounds for recommending the obtained fuel-water emulsion and multicomponent composite fuel for combustion. The technological properties of the obtained fuels improve; besides, the increase in their volume thanks to addition of water should be taken into consideration.

Table 1

№	Properties	State Standtard 10585-99	"Dry" mazut fuel oil M-100	Mazut fuel oil M-100 after cavitation	Mazut fuel oil M-100 with manual water addition (22%)	Fuel-water emulsion MM-100	Fuel-water emulsion MM-100
1.	Wt percent of water, not more than	1.0	0.5	traces	20.8	19	32
2.	Congelation temperature in °C, not more than	25	27	27	26	29	32

(continued)

№	Properties	State Standtard 10585-99	"Dry" mazut fuel oil M-100	Mazut fuel oil M-100 after cavitation	Mazut fuel oil M-100 with manual water addition (22%)	Fuel-water emulsion MM-100	Fuel-water emulsion MM-100
3.	Combustion value (lowest) converted to dry fuel one (not discarded) in kJ/kg,						
	not less than for sulfurous fuel			42811	40440		
	not less than for highly sulfurous fuel	40530 39900	41343			58504	47090

Table 2

№	Properties	Standard for brands (State Standard 10585-99)		Input mazut fuel oil M-40	Fuel-water emulsion MM-100
		40	100		
1.	Wt percent of water, not more than	1.0	1.0	1.0	16.0
2.	Wt percent of sulfur, not more than				
	for sulfurous mazut fuel oil	2.0	2.0		
	for highly sulfurous mazut fuel oil	3.5	3.5	2.3	1.77
3.	Congelation temperature in °C, not more than	10	25		
	for mazut fuel oil from highly sulfurous oil	25	42	24	32

(continued)

№	Properties	Standard for brands (State Standard 10585-99)		Input mazut fuel oil M-40	Fuel-water emulsion MM-100
		40	100		
4.	Combustion value (lowest) converted to dry fuel one (not discarded) in kJ/kg,				
	not less than for sulfurous fuel	40740	40530		43372
	not less than for highly sulfurous fuel	39900	39900	41674	

Claims

1. The method of making a fuel-water emulsion and multicomponent composite fuel uses heating of the hydrocarbon input with the content of water of up to 50 wt % to the temperature of 120°C, processing it with pressure, and cavitation-processing it to make a fine-particle fuel-water emulsion with 0.5 - 5.0 micrometer water particles to subsequently burst hydrocarbon shells with steam for the second-phase fuel spray.

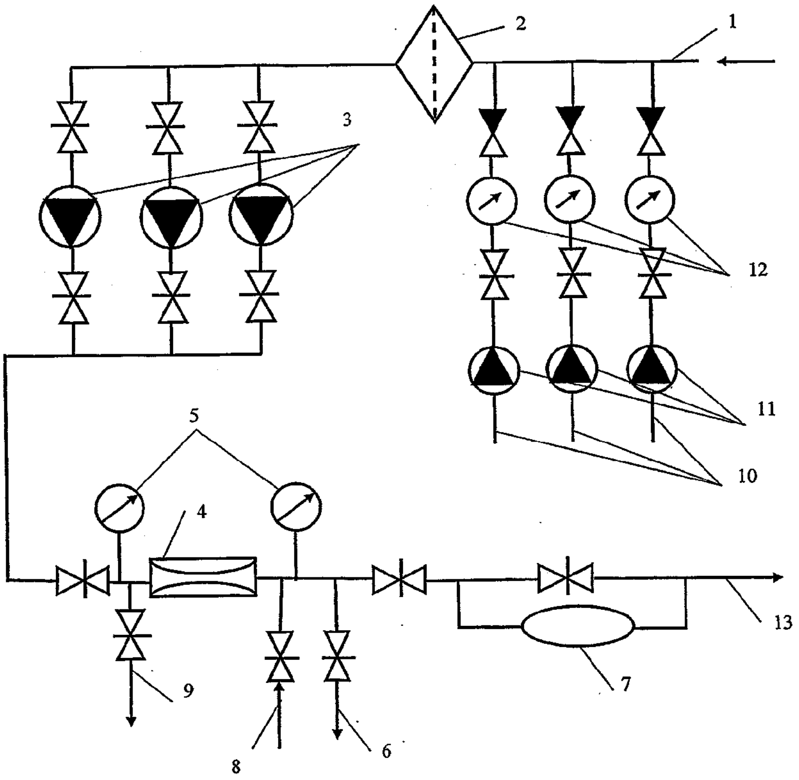


Fig. 1

Fig. 2

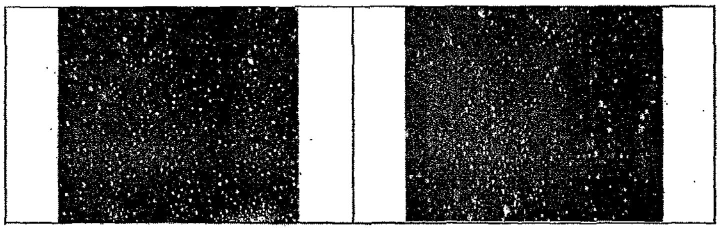
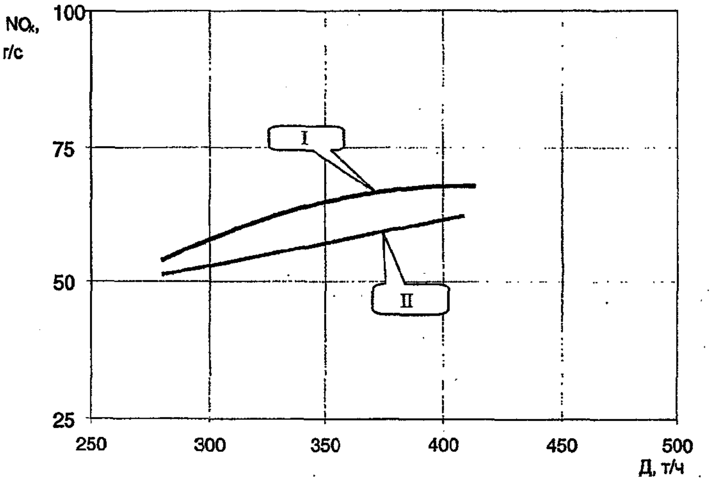


Fig. 3



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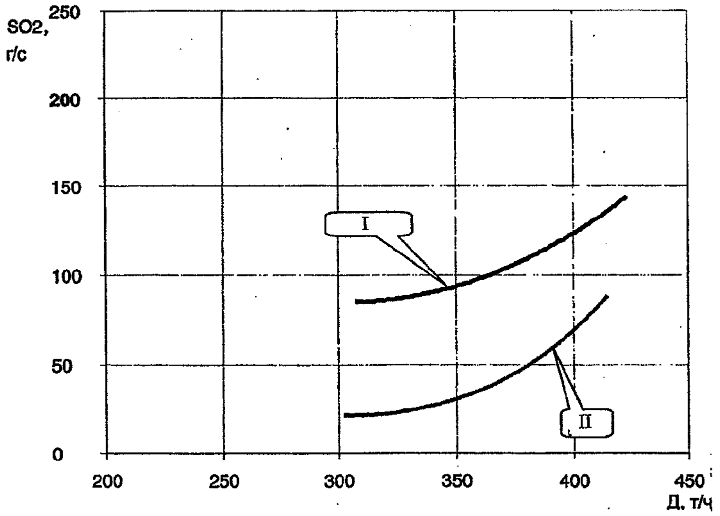

Fig. 5

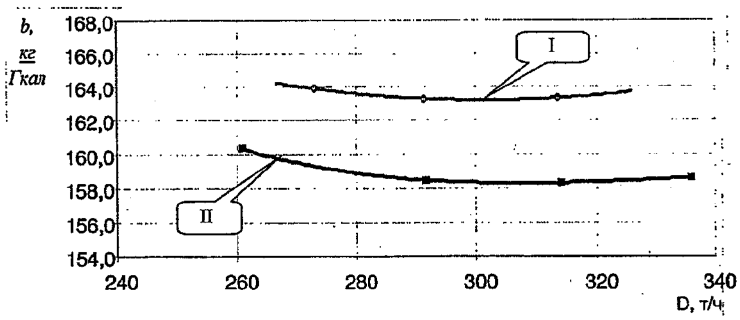
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Fig: 6

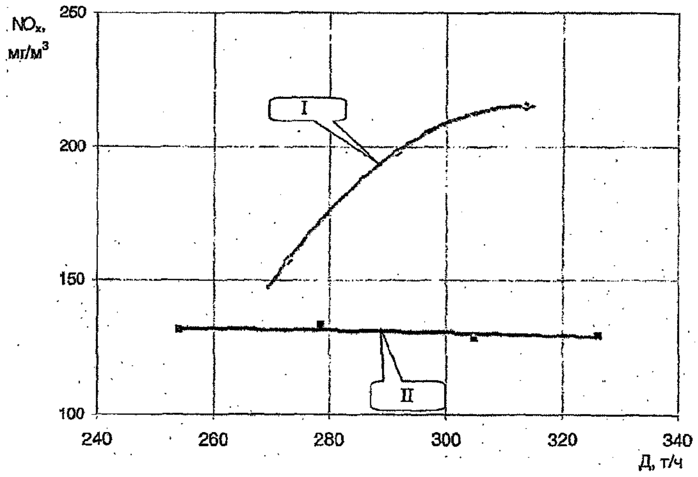

Fig. 7

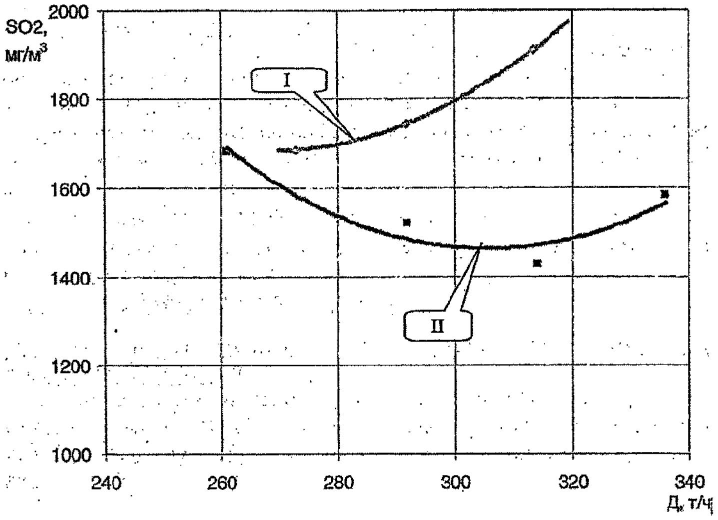
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Fig. 8

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- RU 2278149 **[0004]**