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(54) SYSTEM AND PROCESS FOR HEAVY FUEL OIL PYROLYSIS

(57) The invention provides an abrasion device (300) for continuously removing coke from the inner wall of a rotating reactor (110) comprising a cylindrical part (114) and comprising a base frame (310) with suspensions (311) for mounting auger scrapers (320), wherein said suspensions (311) are mounted at the base frame (310) and connect an upper part (312) and a lower part (313) of the base frame (310); said lower part (313) of the base frame (310) comprises at least one auger scraper (320), wherein said at least one auger scraper (320) comprises a central roller (321) with an outer auger helix (322), said at least one auger scraper (320) being rotatably mounted at cross members (314) at the lower part (313) of the base frame (310) at the ends of the suspensions (311) that are protruding in direction of the bottom of the cylindrical part (114) of the rotating reactor (110).

The invention further provides a system (100) for continuous processing of heavy fuel oil from recycling waste oil and the processing residues of crude oil into useful products comprising means for feeding waste oil; at least one hot-gas filter, at least one condenser, at least one rotating kiln comprising an outer stationary jacket (120) which forms a heating channel (121), and an inner rotating reactor (110), and the abrasion device (300) for removing solid coke from the rotating reactor (110).

The invention further relates to a process for continuous processing of heavy fuel oil from recycling waste oil and the processing residues of crude oil into useful products, preferably with the system of the invention.

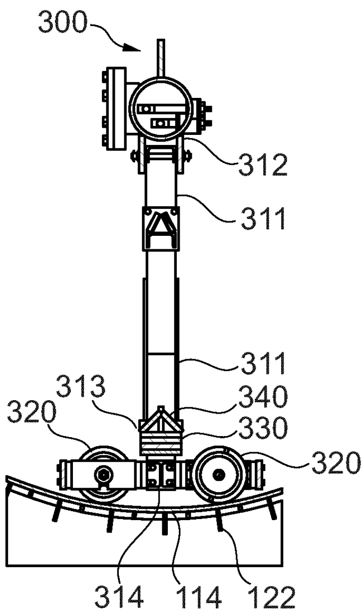

Fig. 10C

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Description

Field of the Invention

[0001] The invention provides an abrasion device (300) for continuously removing coke from the inner wall of a rotating reactor (110) comprising a cylindrical part (114) and comprising a base frame (310) with suspensions (311) for mounting auger scrapers (320), wherein said suspensions (311) are mounted at the base frame (310) and connect an upper part (312) and a lower part (313) of the base frame (310); said lower part (313) of the base frame (310) comprises at least one auger scraper (320), wherein said at least one auger scraper (320) comprises a central roller (321) with an outer auger helix (322), said at least one auger scraper (320) being rotatably mounted at cross members (314) at the lower part (313) of the base frame (310) at the ends of the suspensions (311) that are protruding in direction of the bottom of the cylindrical part (114) of the rotating reactor (110).

[0002] The invention further provides a system (100) for continuous processing of heavy fuel oil from recycling waste oil and the processing residues of crude oil into useful products comprising means for feeding waste oil; at least one hot-gas filter, at least one condenser, at least one rotating kiln comprising an outer stationary jacket (120) which forms a heating channel (121), and an inner rotating reactor (110), and the abrasion device (300) for removing solid coke from the rotating reactor (110).

[0003] The invention further relates to a process for continuous processing of heavy fuel oil from recycling waste oil and the processing residues of crude oil into useful products, preferably with the system of the invention.

Background of the Invention

[0004] The heavy oil (residual oil) produced during oil distillation accounts for about 70 percent of the fuel used in shipping worldwide. From 2020 onwards, ships on the high seas will only be allowed to burn fuel with a Sulphur content of 0.5 percent or below instead of 3.5 percent allowed so far, or will alternatively have to remove the Sulphur from the exhaust gases. As a result of the new regulation, which will be set in force in 2020, environmentally harmful heavy fuel oil cannot be used as a fuel anymore and a large number of international shipping companies will have to replace heavy fuel by more environmentally friendly ship diesel. This in turn has a direct influence on the refineries. There will no longer be a market for their residual heavy oil products in the future.

[0005] For this reason, methods for re-processing the residual oils produced are needed, preferably aiming to the recycling of the heavy oils, e.g. by reintegration into production processes of oils.

[0006] Heavy fuel oil essentially consists of long-chain saturated hydrocarbon compounds (heavy boilers). In order to generate a usable product, processes are needed to degrade these long chain hydrocarbons into shorter chains. One suitable method is pyrolysis, i.e. the so-called "cracking process". The pyrolysis is forced by high temperatures under exclusion of oxygen. Gases, liquids and solids are produced as pyrolysis products.

[0007] Conventionally, pyrolysis is performed in systems comprising a rotating kiln as reactor, in which the cracking of the long chain hydrocarbons of the heavy oil takes place. In the rotating kiln, the heavy oil must be finely atomized and evenly distributed on the inner wall of the rotating kiln. The necessary reaction temperature is usually produced by external heating the rotating kiln and the cracking reaction takes place at the inner wall of the kiln. As a safeguard, the rotating kiln can be purged with a protective medium such as nitrogen. When the cracking reaction takes place, the long chain hydrocarbons are converted into gaseous products and coke is produced as a major byproduct. The coke occurs as a soft coke, which is distributed in the gaseous phase and which has to be eliminated from the gaseous products before their condensation. Coke further occurs as solid coke adhering to the inner wall of the rotating kiln. A growing coke layer at the inner wall of the rotating kiln is disadvantageous, because it forms a heat insulating layer, which disturbs the cracking reaction. As a result, the heavy fuel oil cannot reach the reactor wall and the temperature for initiating the cracking reaction cannot be reached effectively.

[0008] Therefore, several attempts have been made to overcome these disadvantages, and in particular to remove the solid coke occurring at the reactor wall during the cracking reaction.

[0009] CA 2926434 concerns a rotary kiln for the treatment of waste oil and other organic waste. The rotary kiln here is equipped with loosely mounted plates which shall prevent the deposition of coke in the bottom area of the rotary kiln, or shall lead to the scraping off deposited coke. However, during the operation, the loosely mounted plates are distributed randomly within the rotary kiln and after short time of operation, the bottom of the rotary kiln is blocked by a mixture of plates and coke debris. The material flow in the reactor is hindered and the coke cannot be discharged quickly enough, which further increases the size of the bed. This means that the required temperatures cannot be maintained and the heavy fuel oil is sprayed onto the material on the bottom of the reactor and the cracking reaction is thereby disturbed. Therefore, a continuous operation of the rotary kiln as described in CA 2926434 is not possible.

[0010] The German utility model DE 29704044 U1 deals with the problem of the formation of solid layers on the inner wall of rotary kilns resulting from the smoldering of materials containing hydrocarbons, such as residues from heavy oil and coal hydrogenation. To solve this problem, rolling elements are used to clean the inner wall of the drum. These rolling elements, however, are themselves covered with the solid material during operation of the rotary kiln, wherein their effectivity in cleaning the inner wall of rotary kilns is decreased and the maintenance efforts of the entire system is increased.

[0011] DE 69732164 T2 concerns processes for removing impurities from oil. In particular, the invention relates to a device for removing contaminants from used oil, in which device the oil is subjected to evaporation and pyrolysis to form coke. Contaminants such as heavy metals remain in the coke, which can then be separated from the oil. The device comprises a rotating kiln, which is indirectly heated. Also in this device, the problem has to be solved that coke deposited on the reactor walls has to be removed. To solve this problem, the reaction chamber is equipped with granular, crude solids (such as metal chips), which act to chafe and crush coke from the reactor wall. Such system, however, can only be operated discontinuously, because the granular, crude solids are mixed with the coke crushed from the reactor wall during operation. This mixture accumulates in the reactor and needs to be removed regularly from the reactor.

[0012] WO 2020187754 A1 concerns a system for continuous processing of heavy fuel oil from recycling waste oil and the processing residues of crude oil into useful products, said system comprising scraper means that are mounted in a rotating kiln, wherein the distance between the scraper means and the reactor wall is in the range of 0.5 to 2.0 mm. This leads to the fact the coke still accumulates at the reactor wall as a layer with a thickness between 0.5 to 2.0 mm.

[0013] Taken together the problem that coke deposits form on the reactor wall and have to be removed from it during thermal decomposition of heavy fuel oils in rotary reactors is known in the art.

[0014] To solve this problem, devices for mechanical removal of the coke as described above have been developed. However, all these solutions are associated with disadvantages such as no reliable operation, high maintenance efforts as well as the need for discontinuous removal of materials from the reactor and disposal as waste. Therefore, the solutions known in the art do not offer the possibility of processing heavy fuel oil in a reliable continuous process.

Description of the invention

[0015] Accordingly, it was the purpose of the invention to overcome the problems of the prior art and to provide a simple and reliable system and process for the continuous pyrolysis of heavy fuel oil.

[0016] To solve this problem, the invention provides in a first aspect an abrasion device. Said abrasion device comprises a base frame with suspensions for mounting auger scrapers. The suspensions are mounted at the base frame, connect an upper part and a lower part of the base frame and are preferably designed to be telescopic and allow a vertical movement of the lower part of the base frame, which comprises the auger scrapers. The auger scrapers comprise a central roller with an outer auger helix, which is preferably made of steel. The auger scrapers are rotatably mounted at cross members at the lower part of the base frame at the ends of the suspensions that are protruding in direction of the bottom of the rotating reactor. Preferably, each abrasion device comprises one, two or three, preferably two, most preferably three auger scrapers. Further preferably, the rotating reactor of the invention comprises two abrasion devices comprising two to six auger scrapers, preferably four, most preferably six auger scrapers. The auger scraper means are aligned with the reactor wall. In a most preferred embodiment, the auger scrapers are arranged over the entire length of the bottom of the cylindrical part of the rotating reactor. Further preferably, the auger scrapers are arranged alternately on the left and right side of the base frame with the telescopic suspensions, when seen from the top view. This ensures an even load on the telescopic suspensions by the auger scrapers.

[0017] It is desired to keep the thickness of the layer structure of the coke and thus the deteriorating heat transfer as low as possible. Preferably, substantially all coke accumulations at the cylindrical part of the reactor wall shall be removed by the abrasion device of the invention. In order to achieve this goal, the abrasion device of the invention comprises at least one, preferably some, most preferably all of the following further special embodiments:

i. The base frame of the abrasion device is mounted on a rigid central axis within the cylindrical part of the rotating reactor such that any axial movement of the abrasion device is prevented. Only vertical movements of the lower part of the base frame, which comprises the auger scrapers of the abrasion device, are possible through the telescopic suspensions.

ii. The lower part of the base frame further comprises weights to increase the mass of the lower part of the base frame and to increase the contact pressure of the auger scrapers on the coke layer on the reactor wall.

iii. It has been measured by the inventors that the breaking strength of the coke that accumulates on the inner side of the reactor wall, is in the range of 70 N/mm^2 to 90 N/mm^2. Accordingly, the mass of the weights was calculated in such a way that the abrasion device generates a contact pressure of > 70 N/mm^2, preferably > 80 N/mm^2 or > 90 N/mm^2, more preferably 100 N/mm^2 to 150 N/mm^2, on the inner side of the wall of the cylindrical part of the rotating reactor, wherein said contact pressure is calculated on the basis of dead weight of the lower part of the base frame including the auger scrapers and the weights mounted on the lower part of the base frame and the contact surface area of the auger helix on the inner wall of the rotation reactor. Best results were achieved when the abrasion device generates a contact pressure of 120 N/mm^2 on the inner side of the wall of the cylindrical part of the rotating reactor. Due to the telescopic suspensions, the lower part of the abrasion device can always apply the contact pressure preset by the choice of the mass of the weights to the reactor wall without obstruction. Best results in this context means that substantially all of the accumulated coke is scraped from the inner wall of the cylindrical part of the rotating reactor in a continuous manner.

iv. Since the auger scrapers are rotatably mounted at cross members at the lower part of the base frame at the ends of the suspensions that are protruding in direction of the bottom of the rotating reactor, and due to the preset contact pressure, the auger scrapers rotate during operation of the rotating reactor. This generates and ensures a positive movement between the auger scrapers and the inner reactor wall and further supports the breaking of the accumulated coke at the inner reactor wall and the scraping-off of the coke by the auger helix.

[0018] To solve the problem of the invention, the invention further provides a system for continuous processing of heavy fuel from the recycling of waste oil and the processing of residues from crude oil into useful products comprising

- means for feeding waste oil;
- at least one hot-gas filter,
- at least one condenser,
- at least one rotating kiln comprising an outer stationary jacket which forms a heating channel, and an inner rotating reactor, and
- means for removing solid coke from the rotating reactor;

wherein the at least one hot gas filter is configured to separate a naphtha/gasoil fraction after the processing of the heavy fuel oil from a soft coke fraction; and wherein the rotating reactor is configured to recover a solid coke fraction comprising high contaminant content;

characterized in that

said system comprises a number of gas burners arranged along the longitudinal direction and sufficient to evenly and indirectly heat the rotating reactor;

the rotating reactor comprises at least one abrasion device as described in the first aspect of the invention, said at least one abrasion device comprising auger scraper means, wherein said auger scraper means are configured to continuously remove accumulated solid coke from the inner wall of the rotating reactor and converting said accumulated solid coke into powdery coke;

said means for feeding heavy fuel oil comprises a number of spray lances of different length and configured to distribute with nozzles said waste oil evenly along the longitudinal direction within the rotating reactor.

[0019] Said system is preferably configured to operate at a process temperature in the range of 600 to 650 °C, measured at the inner wall of the rotating reactor.

[0020] The continuous cleaning of the inner wall of the rotating reactor is one of the crucial points in the construction of the system according to the invention since the heat transfer is hindered by the layer structure of the coke and thus the cracking process of the heavy fuel oil on the reactor wall and within the volume of the rotating reactor is disturbed. It is a great advantage of the abrasion device and system of the invention comprising said abrasion device that substantially all accumulated coke is removed from the inner wall of the rotating reactor. Compared to prior art technologies, e.g. to the technology disclosed in WO 2020187754 A1, no coke layer is formed the inner wall of the rotating reactor during operation. So, the heat transfer and energy efficiency of the abrasion device and system of the invention is greatly improved compared to technologies known in the prior art.

[0021] In a further embodiment, the rotating reactor is equipped at the lower end of the inclined reactor with a funnel, wherein said funnel comprises auger plates to discharge the material from the rotating reactor. The funnel and the auger plates are preferably made of a suitable material, such as iron or steel or stainless steel.

[0022] Accordingly, the rotating reactor comprises a cylindrical part and a funnel with the auger plates. The cylindrical part has usually a length of 4.50 to 6.00 m. Preferably, the cylindrical part has a length of 5.00 to 5.50 m. Most preferably, the cylindrical part has a length of 5.23 m. The funnel has usually a length of 1.50 to 2.50 m. Preferably, the funnel has a length of 1.80 m to 2.20 m. Most preferably, the funnel has a length of 2.02 m. The cylindrical part and the funnel together usually have a length of 6.00 m to 8.50 m. Preferably, the cylindrical part and the funnel together have a length between 6.50 and 8.00 m. Most preferably, the cylindrical part and the funnel together have a length of 7.25 m.

[0023] The cylindrical part has usually a diameter in the range of 2.40 m to 3.20 m, preferably in the range of 2.60 m to 3.00 m. Most preferably, the cylindrical part has a diameter of 2.80 m. The rotating reactor has two barrel rings, i.e. one barrel ring on each end of the reactor. Each of the barrel rings interacts with a bearing of a frame construction. When the cylindrical part and the funnel together have a length of 7.25 m, the two barrel rings have a distance of 7,00 m.

[0024] A known problem of rotating reactors is that a so-called ovality. Ovality is the degree of deviation from perfect circularity of the cross section of the reactor. In case of the present invention, the ovality, i.e. the deviation from perfect circularity of the cross section of the reactor is in the range of ± 3 mm at the barrel rings.

[0025] A further problem is the so-called deflection over the longitudinal axis of the reactor. The value of the deflection may increase with the length of the reactor.

In case of the present invention, the length of the reactor is relatively short and a value of 1 to 2 mm was calculated for the deflection. However, the rotating reactor of the present invention comprises at the outer wall of its cylindrical part, means that ensure that the heating gas is evenly distributed in the heating tunnel (discussed below). Such means are preferably plates, such as ribbed plates, which are welded on the outer wall of the cylindrical part. These welded ribbed plates on the outer wall of the reactor have a further stabilizing effect, which further decreases the deflection below the value of 1 to 2 mm.

[0026] However, the ovality and deflection of the reactor play a minor role. Deviations from the "roundness" of the reactor are advantageously compensated by the abrasion device of the invention, which allows vertical movements of the lower part of the base frame, which comprises the auger scrapers of the abrasion device, through the telescopic suspensions.

[0027] The advantage of this construction, in particular the combination of the abrasion device of the invention with the funnel comprising auger plates is that the scraped coke is discharged from the rotating reactor continuously in an easy way and without the need of further constructural means, simply by gravity. The discharge of the scraped coke by gravity is further supported by the arrangement of the rotating reactor, which is inclined in direction of the lower end, i.e. towards the funnel comprising auger plates. Preferably, the rotating reactor is inclined at an angle between 2 und 8°, preferably 3 to 6°, most preferably 4 to 5°.

[0028] In a further embodiment, the system of the invention comprises downstream components such as a diverter, double pendulum dampers and screws for discharging the scraped coke. Preferred downstream elements comprise a diverter, a mill or a grinder, rotary valves or double sluice gates, a hot-rolling screw conveyor and a cooling screw conveyor. The solids are conveyed from the rotating reactor into the diverter. In the subsequent downstream elements, the coke must be cooled from the process temperature down to a temperature of e.g. 60 °C in the cooling screw. After passing the cooling screw, the scraped coke may be filled in big bags or other types of containers for storage and further handling. Accordingly, the system of the invention comprises in a further embodiment downstream means for filling the scraped coke into containers, such as Big Bags.

[0029] In order to promote the cracking reaction, the rotating reactor must be heated to reach and maintain the process temperature, which is suitably in the range of 400 to 700°C, preferably between 550 and 700°C, more preferably between 600 and 650°C. In a preferred embodiment, the rotating reactor is heated indirectly. This has the advantage that the occurrence of hotspots or punctual heat in the reactor wall is prevented, which could occur with direct heating. Indirect heating is realized preferably by an outer jacket, which forms a housing and heating channel around the rotating reactor. External burners, such as external gas burners, that are placed outside of the rotating reactor and outside of the housing, are used to produce heat that is blown into the heating channel (the space between the rotating reactor and the outer jacket) of the system of the invention. A further challenge is to apply the required heat evenly over the whole body of the rotating reactor. This problem is solved in the preferred embodiment of the invention in that and number of burners, such as gas burners are arranged to apply indirect heat along the entire length of the rotating reactor. In a further preferred embodiment, 2 to 6 gas burners are used for indirect heating, more preferably 3 to 5 gas burners most preferably 4 gas burners. The number of gas burners, however, may be adopted in accordance with the dimensions of the rotating reactor. Moreover, the gas burners must have an output sufficient to support the cracking reaction in the rotating reactor. The total output of the gas burners is preferably between 500 and 2,000 kW, more preferably between 750 and 1,500 kW, most preferably between 950 and 1.250 kW. In a further preferred embodiment of the invention, the burners are mounted to the heating tunnel via a pre-combustion chamber. In order to prevent heat loss, the pre-combustion chamber and the heating tunnel are insulated.

[0030] To ensure that the heating gas is evenly distributed in the heating tunnel, means are provided on the outer wall of the rotating reactor. Such means are preferably plates, such as ribbed plates, which are made from a suitable material, such as iron, steel or stainless steel. These means increase the surface of the reactor wall and ensure a turbulent flow of the heating gas as well as a more efficient heat transfer into the rotating reactor. The system of the invention therefore comprises in a further embodiment ribbed plates for supporting the distribution of the heated air, wherein said ribbed plates are mounted on the outer wall of the rotating reactor. The number and the dimensions of these ribbed plates are configured in accordance with the dimensions of the system of the invention, i.e. of the rotating reactor.

[0031] The system of the invention further comprise holes in the jacket for directing the heating gas into the space between housing and reactor wall of the rotating reactor.

[0032] A further challenge, which has been solved by the system of the invention, is the even distribution of the heavy fuel oil over the entire length of the rotating reactor. For this reason, the heavy fuel oil is not distributed into the rotating reactor with one spray lance only. The number of spray lances has been rather increased in accordance with the length of the rotating reactor, especially in accordance with the length of the cylindric part of it. Accordingly, the system of the invention comprises more than one, e.g. 2 to 8, preferably 3 to 5, most preferably 4, evenly most preferred 3 spray lances, which guarantee even distribution of the sprayed heavy fuel oil with in the rotating reactor. The spray lances have different lengths in order to distribute the heavy fuel oil with defined parts or areas of the rotating reactor, whereby it is advantageous that the length of the spray lances is selected in order to prevent overlapping spray pattern.

[0033] In this regard, the design of the nozzles, which are mounted at the end of the spray lances in the rotating reactor, has also been optimized. The nozzle used are as fine as possible and do not have a too large spray cone. This construction has the advantage that an overlapping spray pattern is prevented. The use of a flat spray nozzles is not recommended, as these are only to be used for coarse spray patterns. In a preferred embodiment of the invention, the nozzles used at the end of the spray lances have a spray cone with a spray angle at the outlet of the nozzle of approx. 45°. This construction ensures that not too much material is sprayed onto a too small area, because this would deteriorate the heat transfer within the rotating reactor and therefore disturb the cracking reaction.

[0034] Solids, such as coke, are continuously scraped from the rotating reactor wall during its operation, forming a bed of debris in the certain area on the bottom of the rotating reactor. This bed of debris detonates the heat transfer on the reactor wall and into the rotating reactor at least locally. Spraying the heavy fuel oil on the bed of the breeze would lead to an incomplete cracking reaction. In a further embodiment of the invention, the direct action of the nozzles is therefore arranged to spray the heavy fuel oil on areas of the wall of the rotating reactor, which is free of debris of solids and coke.

[0035] The remaining solids, such as soft coke and dust, in the gas stream need also to be separated downstream. The quality of the purified gas is decisive for the stability of the further process. The system of the invention therefore comprises in a further embodiment means for removal of the remaining solids from the gas stream. Suitable means for the removal of the remaining solids from the gas stream are for example cyclones or hot gas filtration systems. Most preferred in accordance with the invention are hot gas filtration systems. A suitable hot gas filtration system comprises e.g. fibre-ceramic filter cartridges. Such a hot gas filter may comprise rigid filter elements, which are suspended in an insulated container with a conical dust collection chamber, wherein the filter cartridges made of robust ceramic fibes are resistant to temperatures up to 850 °C and chemicals. Suitable fiber ceramic materials for this purpose are available in the art. In a further preferred embodiment, the hot gas filter is equipped with means for cleaning the filter cartridges. Such means are e.g. selected from jet valves, which are opened in short intervals (fractions of a second), whereby the filter cartridges are purged with an inert purge gas, such as nitrogen gas at high pressure.

[0036] In a further embodiment, the system of the invention comprises seals between the rotating reactor and the inlet and outlet housings, and a seal between the heating channel and the reactor. In particular, the seals between the rotating reactor and the inlet and outlet housings are important for operating the process of the invention and a reliable manner.

[0037] The system of the invention is in further embodiment equipped with heat exchanger. This has the advantage that the pyrolysis and flue gases can be used for heat recovery, i.e. the thermal energy of the flue gases is used to preheat the combustion air required for the gas burners in order to ultimately save natural energy, i.e. natural gas, and also to reduce the output size of the burners as far as possible. Surprisingly, if the pyrolysis gas is fed via a heat exchanger for residual heat utilization, heat energy can be obtained between 120 and 170 MJ/h at efficiencies between 0.5 and 0.7 with the system of the invention. Accordingly, the system of the invention can be operated in an environmental-friendly manner.

[0038] In a further embodiment, the system of the invention comprises a condenser for separating the heavy boiling hydrocarbons, aqueous phase and inert gas fraction from the dust-free pyrolysis gas. The condenser is suitably arranged in the system after the hot gas filter.

[0039] To ensure the inert environment within the system during continuous operation, the system is operated under slight overpressure in an oxygen free atmosphere.

[0040] In order to facilitate the cracking process in the rotating reactor and to ensure a reliable operation in a continuous manner, the system of the invention is configured to prevent any cold bridges and to keep the temperature of and in the rotating reactor including parts that are connected to the rotating reactor, in the range of the process temperature as described above.

[0041] In a further aspect, the invention provides a process for continuous processing of heavy fuel oil from the recycling of waste oil and the processing of crude oil, into useful products comprising the steps of

- thermal cracking of heavy fuel oil in system according to the invention;
- discharging the process gas from the rotating reactor via the hot-gas filter for separation of soft coke particles and thereafter via the condenser;
- scraping coke from the rotating reactor (110) with the abrasion device (300) according to the invention;
- discharging the powdery coke from the rotating reactor;
- partial condensation of the process gas in a condenser and drain off the resulting naphtha/gas oil mixture into storage tanks for further processing.

[0042] The process of the invention can be described in a general manner as follows: The thermal cracking (pyrolysis) takes place in the rotating reactor of the invention. Feed pumps convey the starting product (heavy fuel oil) from the storage tank to the subsequent subsystems. The oil is mixed with steam on the input side, preferably under ratio control, and injected into the rotating reactor. The pyrolysis takes place in a temperature range between 400 to 700°C, preferably between 450 and 600°C, more preferably between 600 and 650°C, measured at the inner wall of the rotating reactor. The temperature in the inner volume of the reactor is preferably between 450°C and 500°C, most preferably 450°C. The long-chain hydrocarbon compounds are degraded and pyrolysis coke and pyrolysis gas are produced. The coke adheres to a great extent to the reactor wall and forms solid coke, which disturbs thermal flow from the heating channel of the system of the invention into the rotating reactor. The solid coke is therefore removed by auger scrapers and discharging means and conveyed out of the rotating reactor by gravity.

[0043] The pyrolysis gas produced contains a not inconsiderable proportion of solids. These are to be removed directly from the hot gas stream, preferably by means of a hot gas filter, which in a more preferred embodiment of the invention comprises fiber-ceramic filter cartridges. The quality of the purified gas is decisive for the stability of the further process.

[0044] The solids-free pyrolysis gas is a mixture of heavy boiling hydrocarbons, low boiling hydrocarbons and water in the presence of inert gas components which are separated by condensation. The resulting hydrocarbon liquids from heavy boiling hydrocarbons and water are discharged from the system of the invention via defined service lines in a storage tank for further use. The remaining non-condensed gases (low boilers) serve as fuel for the gas heaters of the system of the invention.

[0045] The separated solids are fed to a Big Bag filling system via a hot-rolling screw conveyor and a cooling screw conveyor. The Big Bags are e.g. temporarily stored in a small warehouse before they are shipped for recycling by truck. Recycling of the separated solids may e.g. be done by use as fuel for blast furnaces.

[0046] The specific features of the process of the invention are described in connection with figure 10 below.

[0047] In a further aspect, the invention relates to the use of the gas oil / naphta produced with the system and/or the process of the invention for manufacturing useful products, such as fuel, base oil and base oils products.

[0048] Moreover, the invention relates to the use of the powdery coke produced with the system and/or the process of the invention as fuel in blast furnaces.

[0049] The advantage of this aspect of the invention is that almost any products as well as waste products resulting from the process of the invention are re-usable or recyclable.

[0050] The invention is further illustrated in more detail by eight figures, wherein

- Figure 1 shows a cross-sectional view of the system of the invention;
- Figure 2 shows cross-sectional view of the funnel of the rotating reactor;
- Figure 3 shows a side-view on and into an embodiment of the system of the invention;
- Figure 4 shows another side-view on and into an embodiment of the system of the invention;
- Figure 5 shows a cross-sectional view on an embodiment of the diverter of the system of the invention;
- Figure 6 illustrates the principle, how the direction of rotation and the spraying is coordinated;
- Figure 7 shows an embodiment of the heating tunnel with burners and pre-combustion chamber;
- Figure 8 shows an embodiment the heating tunnel with burner and pre-combustion chamber;
- Figure 9 visualizes the hot gas filter;
- Figure 10 shows an embodiment of the abrasion device of the invention in a top view (Fig. 10A), front view (Fig. 10B) and a side view (Fig. 10C); and
- Figure 11 represents a flowsheet of the process of the invention.

[0051] **Figure 1** shows a cross-sectional view of the system **100** of the invention. The system **100** comprises a rotating reactor **110,** which is equipped with an abrasion device **300** in the cylindrical part **114** of the rotating reactor. Said abrasion device **300** comprises a base frame **310** with suspensions **311** for mounting auger scrapers **320.** The suspensions **311** are mounted at the base frame **310,** connect an upper part **312** and a lower part **313** of the base frame **310** and are telescopic thereby allowing a vertical movement of the lower part **313** of the base frame **310,** which comprises the auger scrapers **320.** The auger scrapers **320** comprise a central roller **321** with an outer auger helix **322,** which is made of steel. The auger scrapers **320** are rotatably mounted at cross members **314** at the lower part **313** of the base frame **310** at the ends of the suspensions **311** that are protruding in direction of the bottom of the cylindrical part **114** of the rotating reactor **110.** The embodiment shown in Figure 1 comprises two abrasion devices **300,** wherein each abrasion device **300** comprises three auger scrapers **320.** The auger scrapers **320** are aligned with the inner wall of the rotating reactor **110** and are arranged over the entire length of the bottom of the cylindrical part **114** of the rotating reactor **110.** The auger scrapers **320** are arranged alternately on the left and right side of the base frame **310** with the telescopic suspensions **311,** when seen from the top view. This ensures an even load on the telescopic suspensions **311** by the auger scrapers **320.**

[0052] In order to remove substantially all coke accumulations from the cylindrical part **114** of the inner wall of the rotating reactor **110,** the abrasion device **300** of the system **100** shown in Figure 1 is characterized by the following further special embodiments:

i. The base frame **310** of the abrasion device **300** is mounted on a rigid central axis **113** within the cylindrical part **114** of the rotating reactor **110** such that any axial movement of the abrasion device **300** is prevented. Only vertical movements of the lower part **313** of the base frame **310,** which comprises the auger scrapers **320** of the abrasion device **300,** are possible through the telescopic suspensions

311.

ii. The lower part **313** of the base frame **310** further comprises weights **330** to increase the mass of the lower part **313** of the base frame **310** and to increase the contact pressure of the auger scrapers **320** on the coke layer on the inner wall of the rotating reactor **110.**

iii. The mass of the weights **330** was calculated in such a way that the lower part **313** abrasion device **300,** which comprises the auger scrapers **320,** generates a contact pressure 120 N/mm^2 on the inner side of the wall of the cylindrical part **114** of the rotating reactor **110,** wherein said contact pressure is calculated on the basis of dead weight of the lower part **313** of the base frame **300** including the auger scrapers **320** and the weights **330** mounted on the lower part **313** of the base frame **300** and the contact surface area of the auger helix **322** on the inner wall of the rotation reactor **110.** Due to the telescopic suspensions **311,** the lower part **313** of the base frame **310** of the abrasion device can always apply the contact pressure preset by the choice of the mass of the weights **330** to the wall of the rotating reactor **110** without obstruction. The breaking strength of the accumulated coke at the inner wall of the rotating reacting reactor **110** was determined to be in the range between 70 N/mm^2 and 90 N/mm^2. Substantially all of the accumulated coke is scraped from the inner wall of the cylindrical part **114** of the rotating reactor **110** in a continuous manner, when the abrasion device **300,** in particular the lower part **313** of the base frame **310** with the auger scrapers **320** generates a contact pressure of 120 N/mm^2 on the inner wall of the cylindrical part **114** of the rotating reactor **110.**

iv. Since the auger scrapers **320** are rotatably mounted at cross members **314** at the lower part **313** of the base frame **310** at the ends of the suspensions **311** that are protruding in direction of the bottom of the rotating reactor **110,** and due to the preset contact pressure, the auger scrapers **320** rotate during operation of the rotating reactor **110** without an additional drive unit, i.e. the rotation of the auger scrapers **320** is driven by the rotation of the rotating reactor **110.**

v. This generates and ensures a positive movement between the auger scrapers **320** and the inner wall of the rotating reactor **110** and further supports the breaking of the accumulated coke at the inner wall of the rotating reactor **110** and the scraping-off of the coke by the auger helix **322.**

[0053] The rotating reactor **110** shown in this embodiment comprises a cylindrical part **114** and a funnel **115** with the auger plates **116.** The cylindrical part **114** has a length of 5.23 m and diameter of 2.80 m. The cylindrical part **114** and the funnel **115** together have a length of 7.25 m. The ovality, i.e. the deviation from perfect circularity of the cross section of the rotating reactor **110** is in the range of ± 3 mm. The value of the deflection over the length of the rotating reactor **110** was calculated with 1 to 2 mm, which is further decreased by the ribbed plates **122,** which are welded on the outer wall of the cylindrical part **114.**

[0054] The rotating reactor **110** is inclined at an angle of 4°, which further supports the transport of the scraped solids by gravity into the direction of the funnel **115.** The funnel **115** is located at the lower end of the inclined reactor **110** and comprises auger plates **116.** The funnel **115** with the auger plates **116** supports the transport of the scraped solids out of the reactor **110** into a diverter (not shown), from which the solids are removed from the system **100** via an outlet **172** through a mill **175** and a doble sluice gate **176.**

[0055] **Figure 2** shows cross-sectional view of the funnel **115** of the rotating reactor **110,** which is equipped with auger plates **116** supports the transport of the scraped solids out of the reactor **110** into a diverter (not shown). For introducing the heavy fuel oil into the reactor, the reactor comprises in the central axis **113** spray lances **150** with nozzles **151.**

[0056] **Figures 3 and 4** show embodiments of a side-view on and into the system **100** of the invention. The system **100** comprises an outer jacket **120** which forms a housing of the system **100.** Between the housing **120** and rotating reactor **110,** a heating channel **121** is formed. Four gas burners **130** are mounted in a pre-combustion chamber **140** outside the rotating reactor and outside the housing and are connected to the heating channel **121** via connecting pipes **123.** With this construction, an indirect heating of the reactor **110** is achieved. The indirect heating prevents the formation of punctual heat or hot spots, which otherwise may occur upon direct heating. To ensure an even heat distribution within the heating channel **121,** the rotating reactor **110** is equipped with ribbed plates **122,** which are fixed on the outer wall of the reactor **110.** The system **100** comprises four spray lances **150** with nozzles **151.** In figures 3 and 4, the spray cones **152** of the nozzles **151** are indicated. It can be seen from figures 3 and 4 that the spray cones **152** show non-overlapping pattern in order to support an even distribution of the heavy fuel oil sprayed into the reactor **110** and to prevent local overdosing of heavy fuel oil in the reactor **110.** The system **100** further comprises the abrasion device **300** of the invention (not shown in Figures 3 and 4).

[0057] In **Figure 5,** it is shown that the funnel **115** of the rotating reactor **110** protrudes into the diverter **170. Figure 5** shows a cross-sectional view of an embodiment of the diverter **170.** The diverter **170** comprises at the lower end a funnel **171** with an outlet **172** for the solids, which fall through a mill (not shown) into a double sluice gate (not shown) by gravity and are discharged thereby from the system **100.** On the upper end, the diverter **170** comprises an outlet for the pyrolysis gas, which is connected to the hot gas filter (not shown). The diverter **170**

further comprises a maintenance opening **174.**

[0058] Figure 6 illustrates the principle, how the direction of rotation (indicated by the arrow) and the spraying is coordinated in the reactor **110.** During operation of the system **100,** a debris of scraped solids **153** is formed, which accumulates at a certain position in the reactor **110** due to the rotation of the reactor **110.** The nozzles **152** are oriented such that spraying of the heavy fuel oil into the direction of the accumulated debris **153** is prevented, i.e. the heavy fuel oil is sprayed on areas of the inner wall **114** of the reactor **110,** which are free from debris **153** of solids. This construction ensures that the heavy fuel oil sprayed into the reactor **110** contacts the inner wall **114** of the reactor **110** directly, wherein the reactor wall **114** has the required reaction temperature of 600 to 650 °C.

[0059] Figures 7 and 8 show embodiments of the housing **120** of the system **100,** which forms the heating chamber **121.** Four gas burners **130** are connected via connector pipes **123** to the heating chamber **121.** The heating pipes **123** are part of a pre-combustion chamber **140.** Further shown in **Figure 8** is the seal **160** of the central axis **113** and a bearing **190** of the rotating reactor **110.** The housing further comprises an opening **160** for exhaust gas.

[0060] Figure 9 shows the hot gas filter **180** comprising a filter housing **181** and pressure lines **182** for introducing purge gas into the hot gas filter **180** via purge gas inlet **186.** The cleaning of the filter cartridges **184** with purge gas, such as nitrogen, is controlled by jet valves **182.** The pyrolysis gas is introduced into the hot gas filter via inlet **185.** The hot gas filter **180** comprises at the lower end a conical form, which ends with an outlet **188** for the solids that are removed from the pyrolysis gas. The solids fall into the diverter **170** by gravity. The hot gas filter **180** further comprises an outlet **189** for the solids-free pyrolysis gas into direction of the condenser (not shown). For proper operation, the hot gas filter **180** comprises a backflush tank **187.**

[0061] Figure 10 shows an embodiment of the abrasion device **300** of the invention with the features as detailed in Fig. 1, wherein Fig. 10A is a top view, Fig. 10B is a front view and Fig. 10C is a side view of the abrasion device **300.** In addition to the features detailed in Fig. 1, the weights 330 are covered by a roof **340,** which prevents the accumulation of off-scraped coke powder on the weights of the abrasion device **300,** which supports the maintenance of the contact pressure of 120 N/mm^2 on the inner side of the wall of the cylindrical part **114** of the rotating reactor **110** exerted by the lower part **313** of the base frame **310** with the auger scrapers **320,** which comprise a central roller **321** and an auger helix **322.** The lower part **313** of the base frame **310** comprises a further frame **315** to increase the stability of the lower part **313** of the base frame **310.**

[0062] Figure 11 represents a flowsheet of the process of the invention. The process according to Figure 10 can be described as follows:

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[0063] The system **100** of the invention is fed with the heavy fuel oil from storage tanks via a pump and a pressure line. In order to ensure a reliable process, a second pump may be kept in reserve. The pressure line to the rotating reactor 110 is electrically heated with an operation temperature in the range of 50 to 80 °C, preferably 60 to 70 °C, most preferably of 65 °C, because a lower temperature results in an increase in viscosity of the heavy fuel oil and thus in increased pressure losses.

[0064] The heavy oil must be finely atomized, coated with a protective medium and evenly distributed on the inner wall **114** of the rotating reactor **110.** In the rotating reactor **110** the cracking reaction takes place.

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[0065] As described for the system **100** of the invention above, the heavy fuel oil is fed into the rotating reactor **110** via a number of spray lances **150** comprising nozzles **151** in order to achieve a uniform spray pattern but to also to prevent an overlapping spray pattern of the individual nozzles **151.** For example, for a rotating reactor **110** of approx. 4 m length and with a diameter of 2.8 m, four nozzles **151** are used to meet the prerequisites of the spray pattern. In order to decouple the nozzles **151** hydraulically from each other and to be able to lock and flush them individually in the event of an operational malfunction, they are fed individually into the reactor **110** via separate spray lances **150** of different length. The input feed is thus divided into four identical partial feeds. The required protective film is achieved by dosing steam in a ratio of approx. 1: 10 with controlled quantities. Static mixers are used to achieve a largely homogeneous mixture of oil and steam.

[0066] The required operating temperature of 500 to 600°C at the inner wall **114** of the rotating reactor **110** is achieved by four gas burners **130** with a 250 kW output, operated with natural gas or recycled pyrolysis gas. In a heat exchanger, the combustion air is preheated with the hot flue gases according to the counterflow principle.

[0067] Coke adhering to the rotating reactor wall **114** is removed by scraping and conveyed due to the inclined position rotating reactor **110** towards the outlet of the reactor **110** into the diverter. The solid material accumulates at the lower end of the diverter and is discharged by a separating system via a mill and double sluice gate. The gas flow is discharged at the upper outlet of the diverter. The diverter as well as the downstream system components between reactor **110** and condenser are electrically heated at a holding temperature of **550°C.** The temperature of the diverter is determined by the temperature of the reactor **110.** The high temperatures are important to prevent condensation in the system components before the condensation stage in order to prevent sticking and clogging of the system components.

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[0068] Solid particles contained in the gas stream are filtered in the downstream hot gas filter 180.

[0069] Rigid filter elements **184** are suspended in an insulated container **181** with a conical dust collection chamber at the lower end, which comprises filter cartridges **184** made of robust ceramic fibers resistant to temperatures up to 850 °C and chemicals. The pyrolysis gas is introduced laterally in the lower part of the filter via inlet **185,** where the dust containing gas is deflected in such a way that larger particles are already separated here as a result of gravity forces. The pyrolysis gas, which is still loaded with fine dust, now flows through the filter elements **184** suspended in the filter container from the outside to the inside, whereby the dust is separated on the surface of the filter cartridges **184.** The now dust-free pyrolysis gas reaches the gas outlet **189** via the filter head and is still at a temperature level sufficient for the subsequent condensation.

[0070] The filter elements **184** located in the hot gas filter **180** are grouped into several filter groups, which can be shut off separately towards the outlet. Differential pressure and/or time-controlled, one chamber at a time is decoupled from the gas cleaning process, while the gas filtration continues to run normally via the filter elements **184** of the remaining chambers. To clean the filter elements, jet valves **182** of the shut-off chamber are opened one after the other for fractions of a second, whereby purge gas (N_2 / 300°C) flows into the interior of the filter cartridges **184** at high pressure via pressure lines **183.** This short rinsing impulse is sufficient to blow off the filter cake. The "offline" cleaning process means that the dust is not immediately drawn back onto the filter elements **184,** but falls downwards into a dust collection chamber. Since only small quantities of purge gas are used for pulse cleaning, there is no temperature reduction in the gas and dust collection chamber of the filter **180,** which is also sufficiently heat-insulated and electrically heated (500 °C). The dust falls into the diverter **170** and is discharged by the operation of the mill and the double sluice gate, which is also used for discharging the scraped coke from the lower end of the rotating reactor **110.**

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[0071] The dust-free pyrolysis gas is fed to the condensation stage via the shortest possible route at 550°C process temperature. In the condenser, heavy boiling hydrocarbons, aqueous phase and inert gas fraction are separated. The essential condensation products are gas oil/naphtha and water. These are collected in a storage container and, after a certain dwell time, separated in a level-controlled manner and transported to downstream plants or storage tanks for further use.

[0072] The non-condensable residual gas flow is fed into an exhaust system.

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[0073] In the regular operation of the system **100** of the invention the low-boiling hydrocarbons (methane, ethane, propane, butane, pentane) comprised in the produced gas, are fed as fuel to the gas burners **130** to heat the rotating rector **110.**

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[0074] The coke produced exits the diverter **170** and the hot gas filter **180** at 550 °C process temperature. With a mill and a double sluice gate, the coke is discharged under gas-tight conditions to the downstream equipment. A hot-rolling screw conveyor collects the material flow and conveys it to a cooling screw conveyor. The coke is cooled down to a temperature of 60 °C in the cooling screw. Subsequently it is filled into Big Bags. The Big Bags are inflated with nitrogen prior to filling, which in turn inertises the conveying and cooling screws in counterflow to the coke. The Big Bags are preferably dustproof and conductive.

Advantages of the invention

[0075] The system and process of the invention have several advantages compared to the conventional systems and processes. One main problem associated with cracking of heavy fuel oil is the formation of coke which adheres at the reactor wall at one hand and which is partly distributed in the gaseous reaction products as soft coke and dust. With the system and process of the invention, it is possible for the first time to operate a pyrolysis reactor in a reliable and continuous manner over long time periods, because means and methods are provided to effectively remove the coke from the reactor wall as well as from the gaseous reaction products continuously. The system further solves problems like the prevention of hot spots in the reactor by indirect heating of the rotating reactor with a hot gas stream produced by external gas burners outside the pyrolysis reactor. Moreover, the entire system is temperature controlled to prevent cold points and undesired condensation in the reactor and associated assemblies.

[0076] The system of the invention further fulfills today's environmental requirements. Almost any products resulting from the process of the invention are further used or recycled, such as gas oil /naphta for the production of fuel and recycling oils, such as base oil and base oil products. In a heat exchanger, the combustion air is preheated with the hot flue gases according to the counterflow principle. The pyrolysis gas produced with the method of the invention is re-used for producing the required process heat with the gas burners of the system. The scraped coke is further used as fuel for blast furnaces.

List of Reference numerals

[0077]

100	System of the invention
110	Rotating reactor
113	Central axis, rigid central axis
114	Cylindrical part of the rotating reactor
115	Funnel
116	Auger plates
120	Outer jacket, housing
121	Heating channel

122 Ribbed plates
123 Connection between heating channel and pre-combustion chamber
130 Gas burner
140 Pre-combustion chamber
150 Spray lance
151 Nozzle
152 Spray cone of a nozzle
153 Debris of scraped coke
160 Seal
170 Diverter
171 Funnel for solids
172 Outlet to double sluice gate
173 Outlet for pyrolysis gas to hot gas filter
174 Maintenance opening
175 Mill, grinder
176 Double sluice gate
180 Hot gas filter
181 Filter housing
182 Jet valves
183 Pressure lines for purge gas
184 Filter cartridges
185 Inlet for pyrolysis gas
186 Inlet for purge gas
187 Backflush tank
188 Outlet for solids
189 Outlet for pyrolysis gas in direction to the condenser
190 Reactor bearing
200 Feed
210 Reactor
220 Hot-gas filtration
230 Condensation
240 Gas exhaust
250 Solids handling
300 Abrasion device
310 Base frame
311 Suspension
312 Upper part of base frame
313 Lower part of base frame
314 Cross member
315 Frame
320 Auger scraper
321 Central roller
322 Auger helix
330 Weights
340 Roof

Claims

1. An abrasion device (300) for continuously removing coke from the inner wall of a rotating reactor (110) comprising a cylindrical part (114) and comprising a base frame (310) with suspensions (311) for mounting auger scrapers (320),

wherein said suspensions (311) are mounted at the base frame (310) and connect an upper part (312) and a lower part (313) of the base frame (310);
said lower part (313) of the base frame (310) comprises at least one auger scraper (320), wherein said at least one auger scraper (320) comprises a central roller (321) with an outer auger helix (322), said at least one auger scraper (320) being rotatably mounted at cross members (314) at the lower part (313) of the base frame (310) at the ends of the suspensions (311) that are protruding in direction of the bottom of the cylindrical part (114) of the rotating reactor (110).

2. The abrasion device (300) of claim 1, wherein said suspensions (311) are telescopic, thereby allowing a vertical movement of the lower part (313) of the base frame (310) which comprises the at least one auger scraper (320).

3. The abrasion device 300 of claim 1 or 2, wherein said abrasion device 300 comprises three auger scrapers (320).

4. The abrasion device 300 according to any one of claims 1 to 3, wherein said auger scrapers 320 are arranged alternately on the left and right side of the base frame 310 with the telescopic suspensions 311, when seen from the top view.

5. A system (100) for continuous processing of heavy fuel oil from recycling waste oil and the processing residues of crude oil into useful products comprising

- means for feeding waste oil;
- at least one hot-gas filter,
- at least one condenser,
- at least one rotating kiln comprising an outer stationary jacket (120) which forms a heating channel (121), and an inner rotating reactor (110), and
- means for removing solid coke from the rotating reactor (110);

wherein the at least one hot gas filter is configured to separate a naphtha/gasoil fraction after the processing of the heavy fuel oil from a soft coke fraction; and
wherein the rotating reactor (110) is configured to recover a solid coke fraction comprising high contaminant content;
characterized in that
said system (100) comprises a number of gas burners (130) arranged along the longitudinal direction and sufficient to evenly and indirectly heat the rotating reactor (110);
the rotating reactor (110) comprises at least one abrasion device (300) according to any one of claims 1 to 3, wherein said at least one abrasion

device (300) is arranged inclined and are configured to continuously remove accumulated solid coke from the inner wall (114) of the rotating reactor (110) and converting said accumulated solid coke into powdery coke;
said means for feeding heavy fuel oil comprises a number of spray lances (150) of different length and configured to distribute with nozzles (151) said waste oil evenly along the longitudinal direction within the rotating reactor (110).

6. The system (100) of claim 5, wherein said system (100) comprises one or two abrasion devices (300), wherein each of said abrasion devices (300) comprises one, two or three, preferably three auger scrapers (320), and wherein said auger scrapers are aligned with the inner wall of the rotating reactor (110) and are arranged over the entire length of the bottom of the cylindrical part (114) of the rotating reactor (110).

7. The system (100) according to any one of claims 5 or 6, wherein a lower part (313) of a base frame (310) of the abrasion device (300), which comprises the auger scrapers (320), is movable in vertical direction through telescopic suspensions (311) of the base frame (310).

8. The system (100) according to claim 7, wherein the lower part (313) of the base frame (310) further comprises weights (330), wherein said weights (330) increase the mass of the lower part (313) of the base frame (310) and increase the contact pressure of the auger scrapers (320) on the coke layer on the inner wall of the rotating reactor (110).

9. The system according to claim 8, wherein the lower part (313) of the base frame (310) of the abrasion device (300), which comprises the auger scrapers (320), exerts a contact pressure in the range of 100 N/mm^2 to 150 N/mm^2, preferably 120 N/mm^2 on the inner wall of the rotating reactor (110).

10. The system (100) according to any one of claims 5 to 9, wherein the auger scrapers (320) rotate during operation of the rotating reactor (110) and wherein the rotation of the auger scrapers (320) is driven by the rotation of the rotating reactor (110).

11. The system (100) according to any one of claims 5 to 10, wherein the rotating reactor (110) is inclined at an angle between 2° and 8°, preferably at 4 ° in order to continuously discharge the powdery coke from the rotating reactor (110) by gavity.

12. The system (100) of any one of claims 1 to 11, **characterized in that** said system (100) further comprises a funnel (115) comprising auger plates (116) for discharging powdery coke form the rotating reactor (110).

13. The system (100) of any one of claims 1 to 12, **characterized in that** said system (100) comprises four spray lances (150) of different length, said spray lances (150) comprising nozzles (151) which project the heavy fuel oil evenly into the rotating reactor (110) volume and onto the inner wall (114) of the rotating reactor (110.

14. The system (100) of any one of claims 5 to 13, **characterized in that** the rotating reactor (110) is heated indirectly by gas burners (130), which are mounted to the heating channel (121) via a pre-combustion chamber (140).

15. A process for continuous processing of heavy fuel oil from the recycling of waste oil and the processing residues of crude oil, into useful products comprising the steps of

- thermal cracking of heavy fuel oil in a system (100) according to any of claims 5 to 14;
- discharging the process gas from the rotating reactor (110) via a diverter and a hot-gas filter for separation of soft coke particles and thereafter by a condenser;
- scraping coke from the rotating reactor (110) with the abrasion device (300) according to any one of claims 1 to 4;
- discharging the scraped powdery coke from the rotating reactor (110);
- partial condensation of the process gas in condensers and drain off a resulting naphtha/-gas oil mixture into storage tanks for further processing.

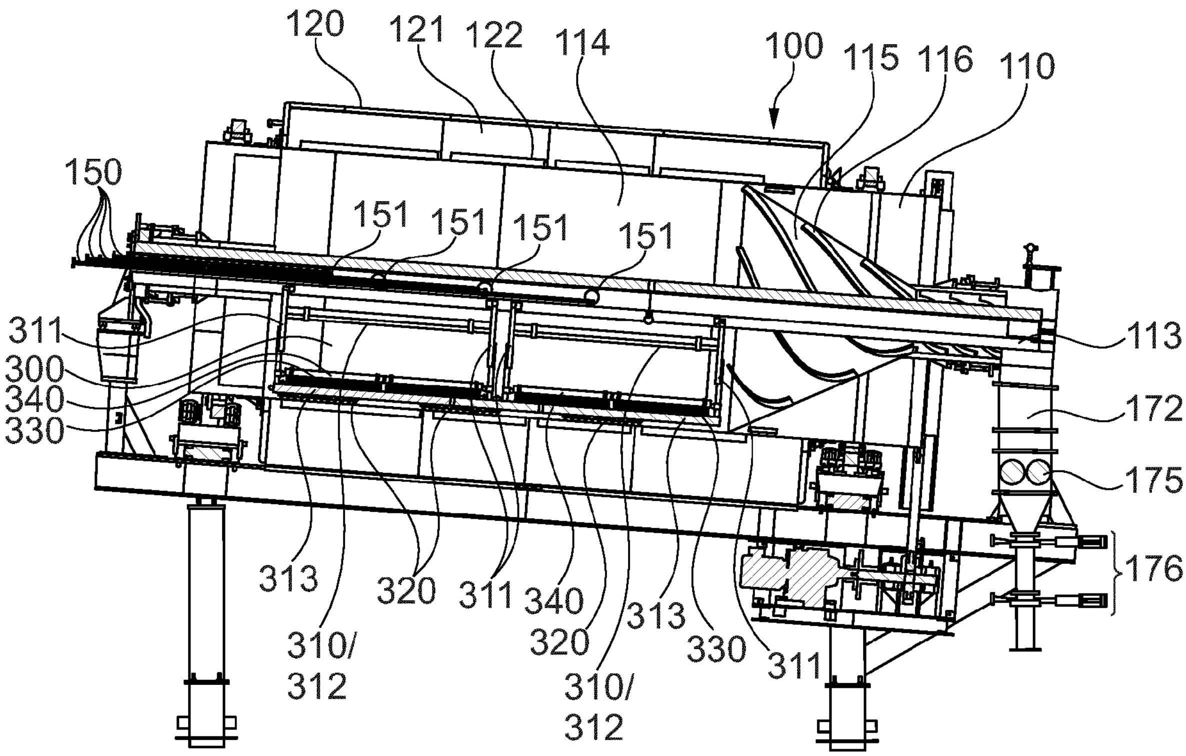
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Fig. 1

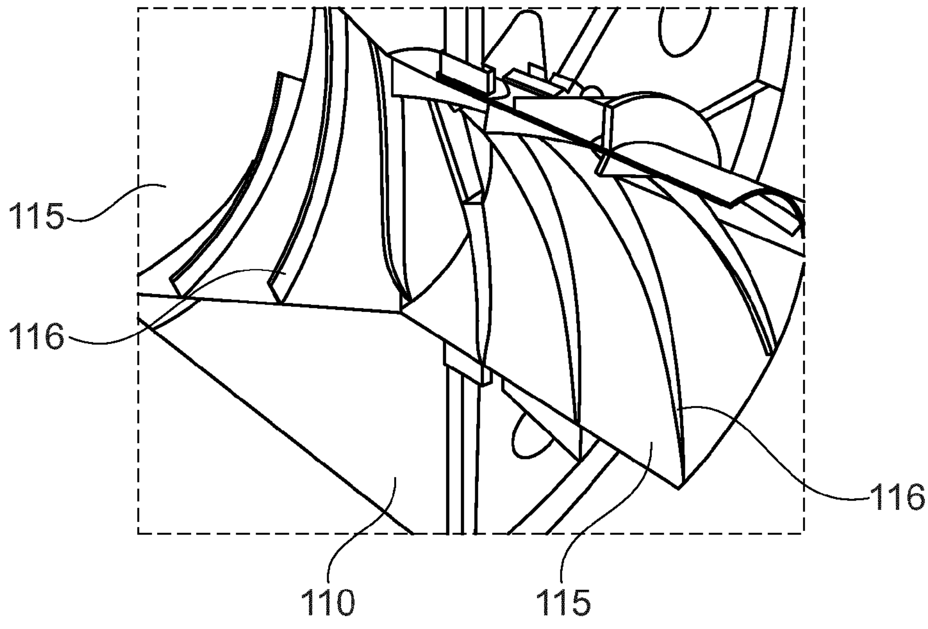
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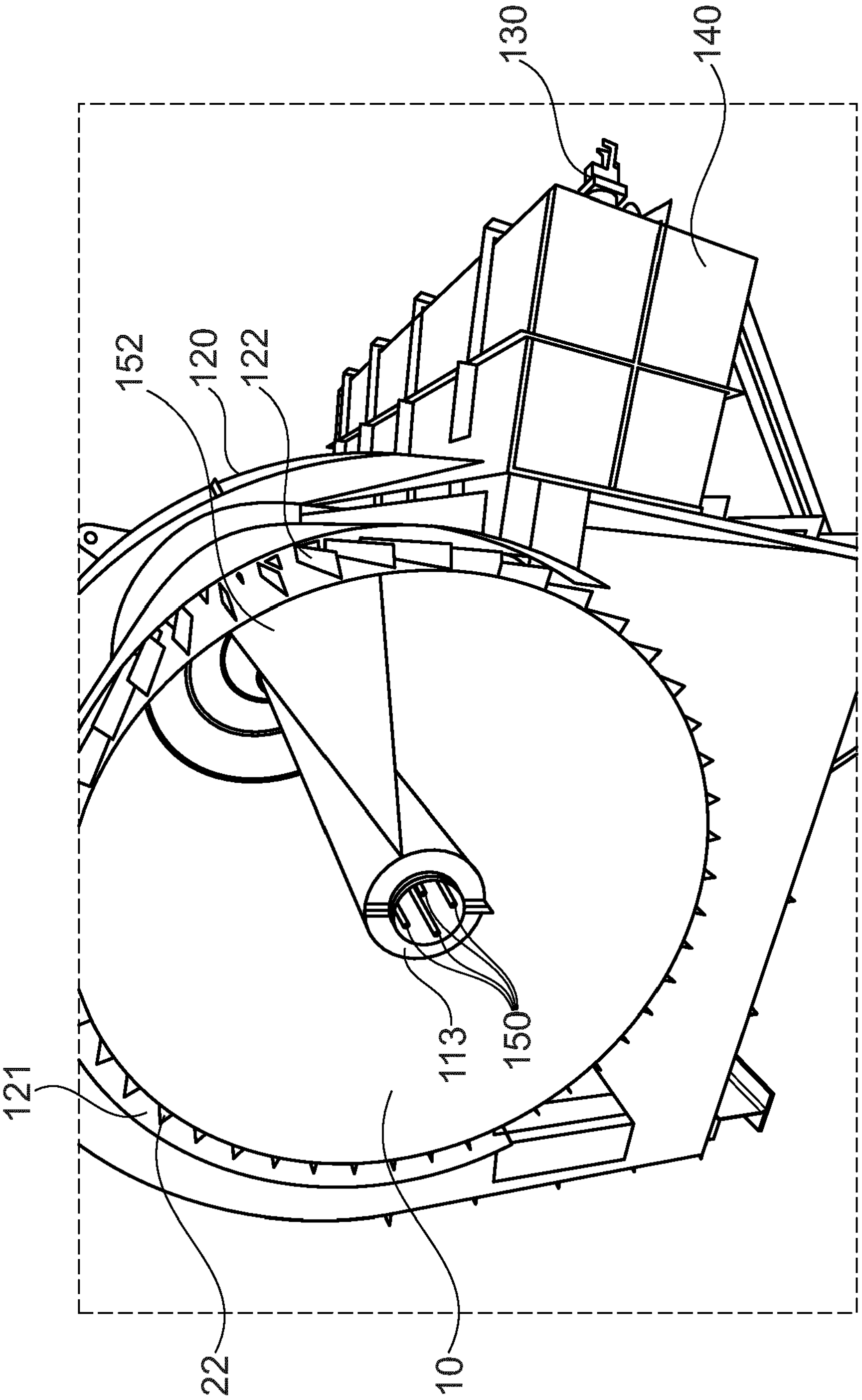
Fig. 2



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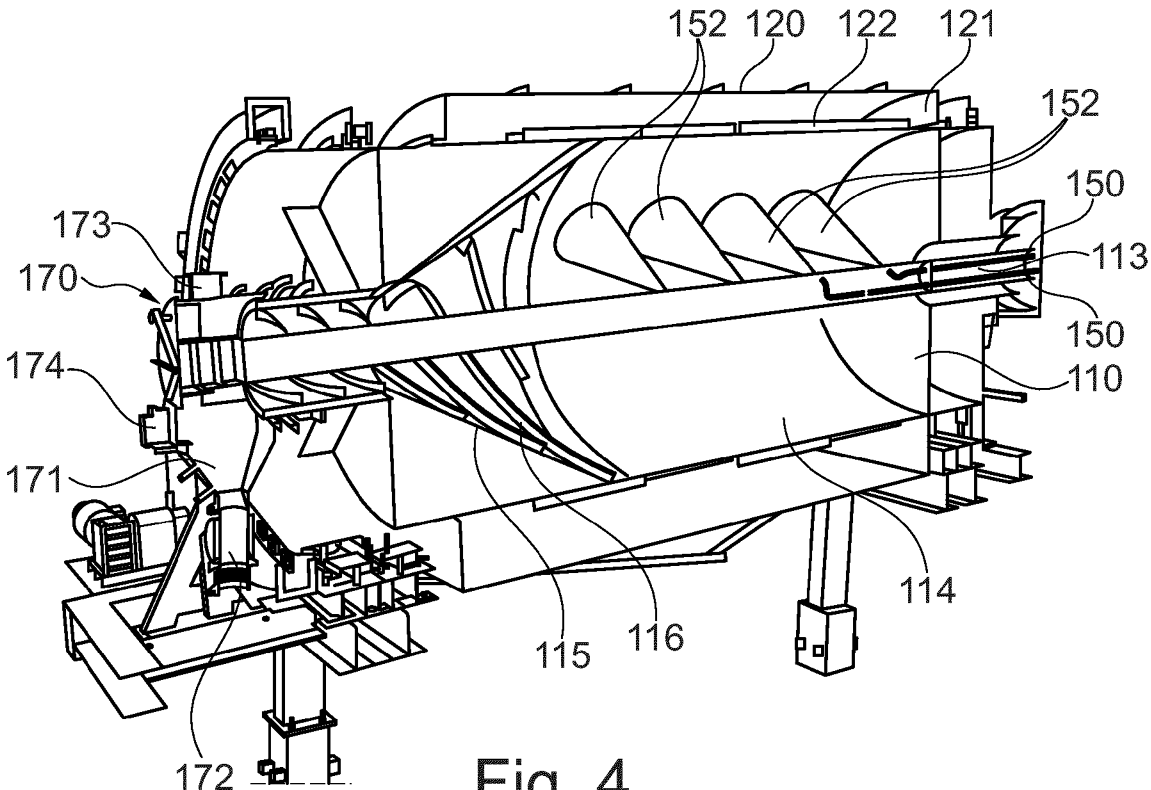
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Fig. 4

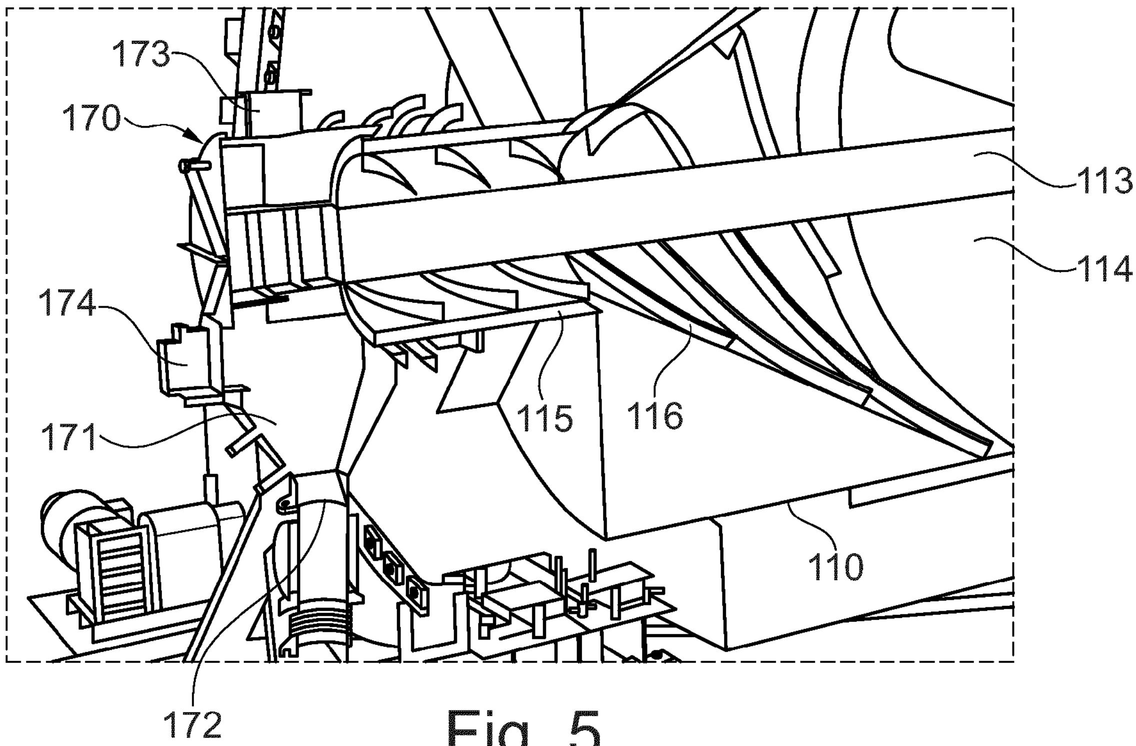
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Fig. 5

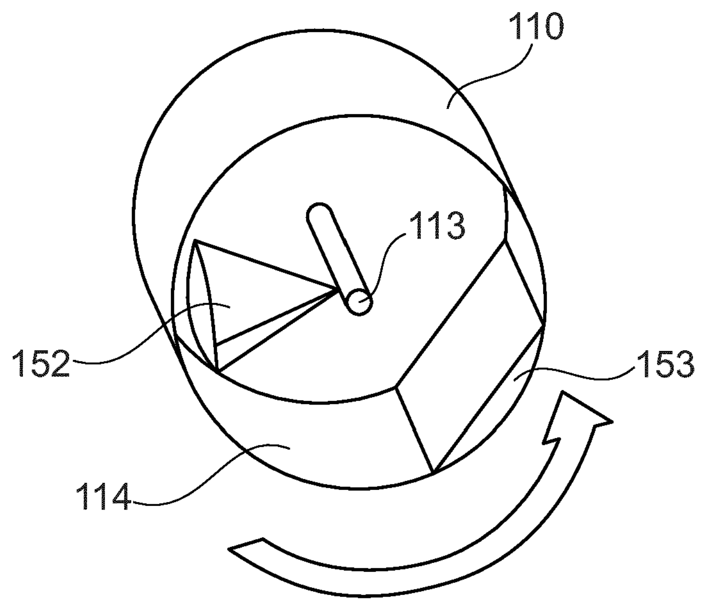

Fig. 6

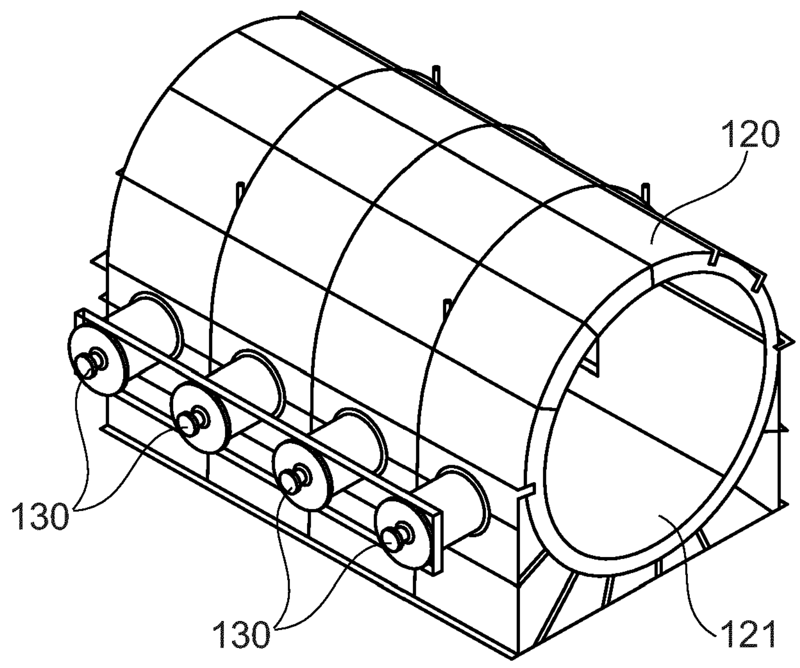

Fig. 7

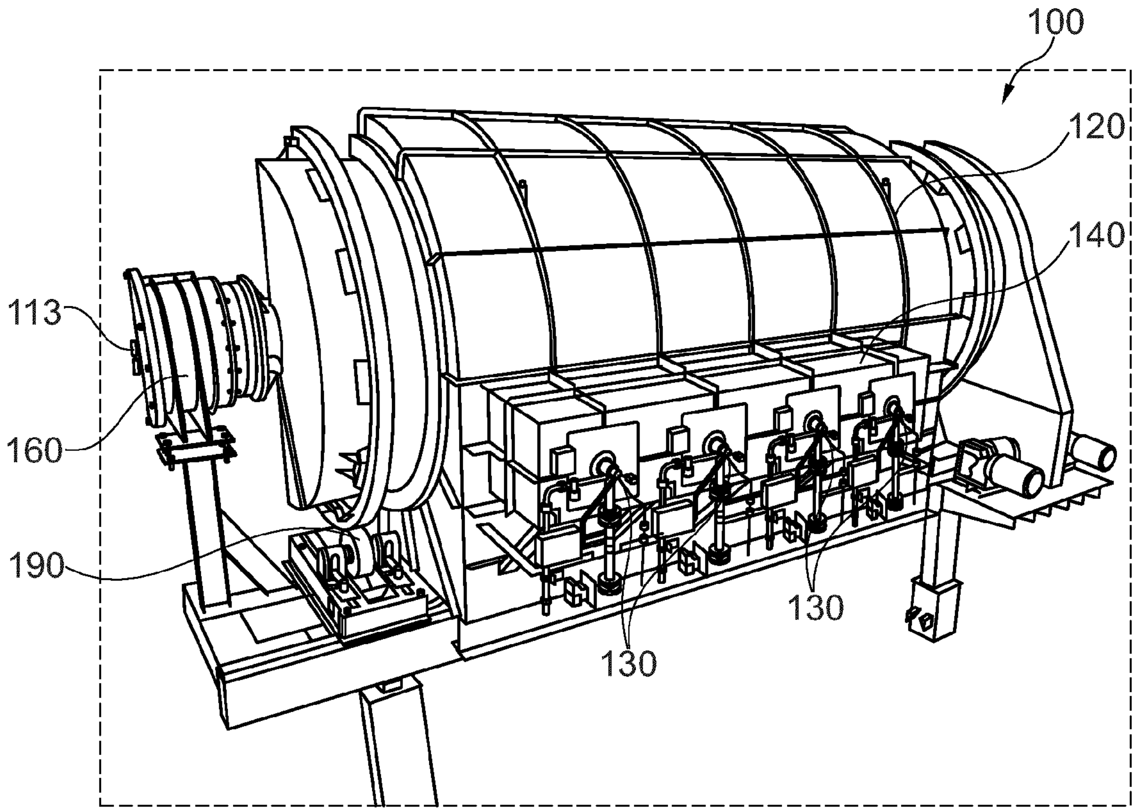
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Fig. 8

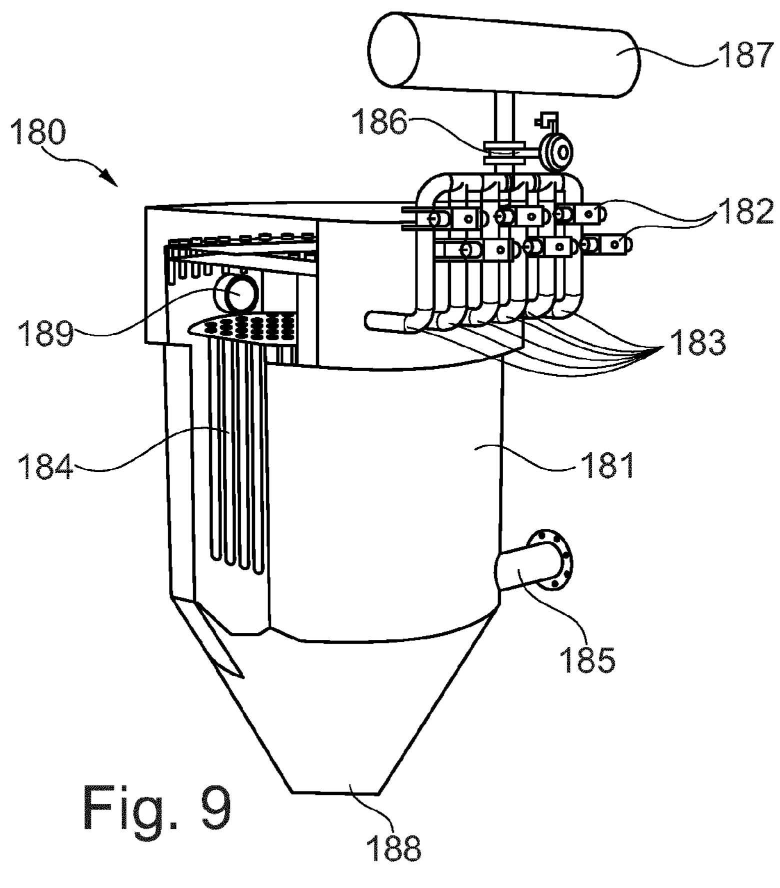
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Fig. 9

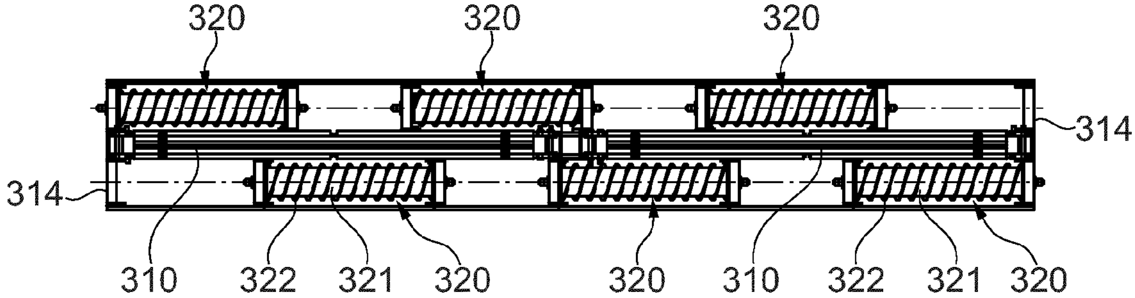

Fig. 10A

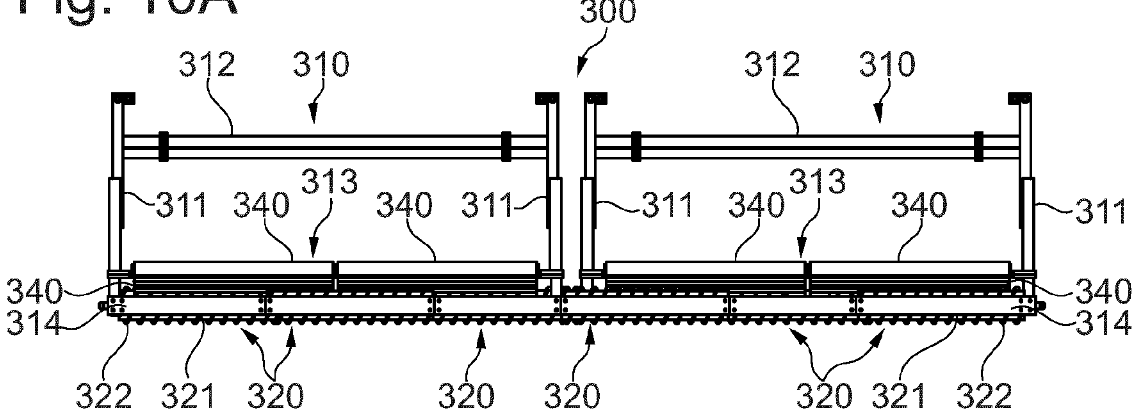

Fig. 10B

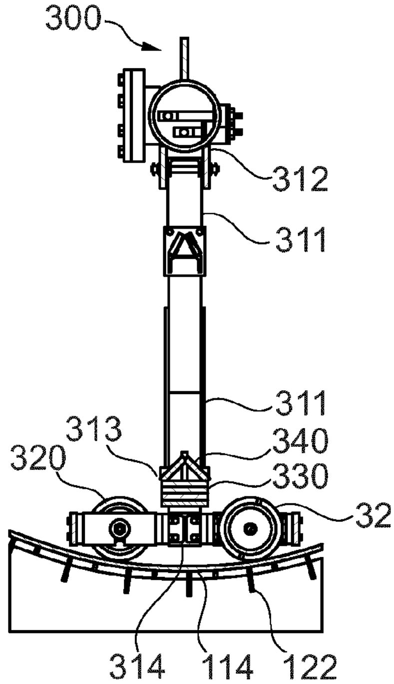

Fig. 10C

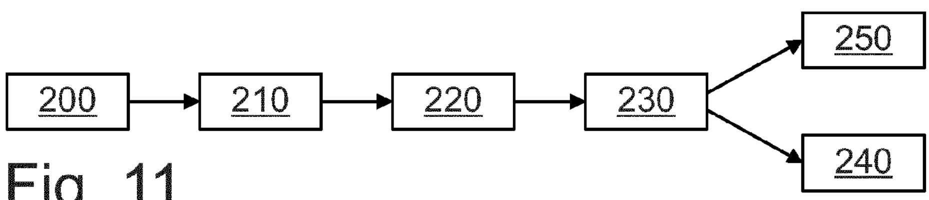

Fig. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 0708

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Place of search	Date of completion of the search	Examiner
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