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(54) PLANT AND PROCESS FOR CONVERSION OF PLASTIC RAW MATERIAL TO FUEL

(57) A plant configured to convert plastic materials into usable fuel, comprising a feedstock supply system for the storage and providing of the plastic raw material in the system, a material preparatory system for preparing the raw material prior to the conversion, a preheating line for increasing the temperature of the plastic raw material, a thermolysis reactor for processing the plastic raw material, one or more oil condensers that are connected to the material preparatory system and a distillation tower that is connected to one or moil oil condensers.

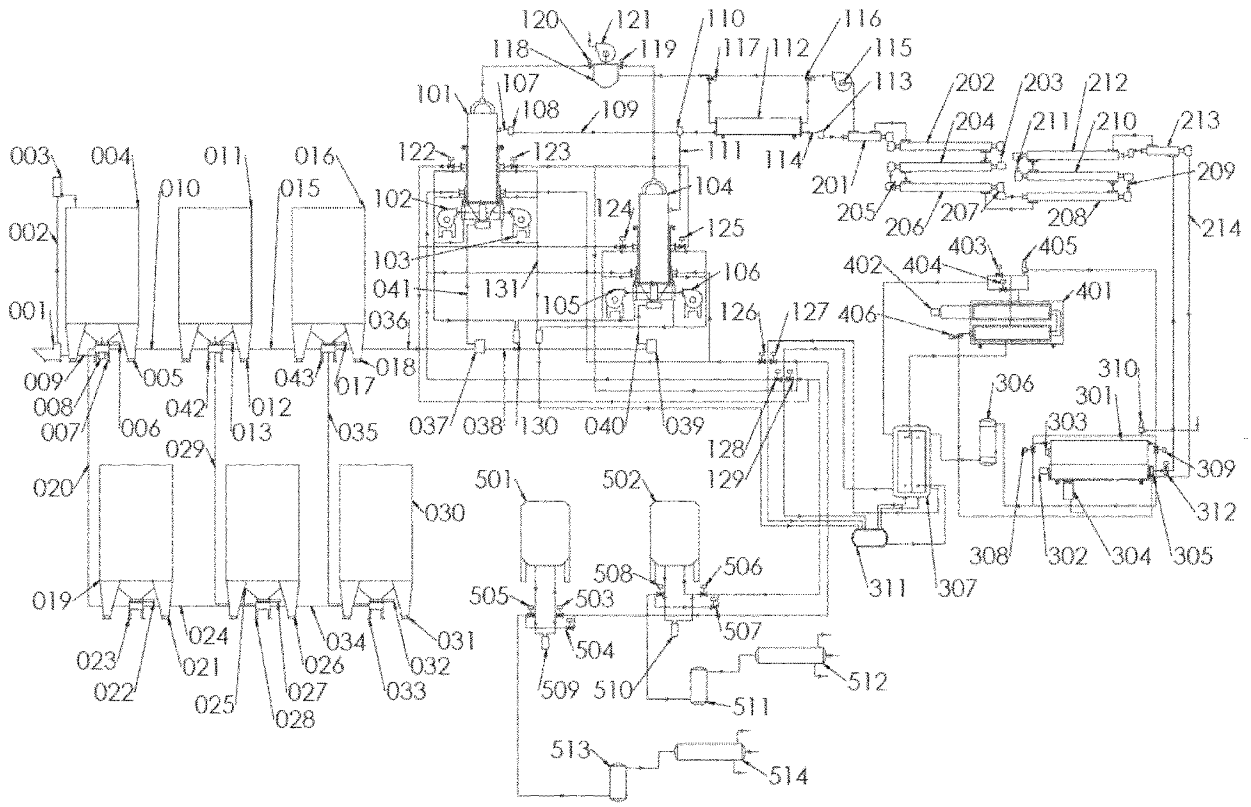

Figure 1

EP 4 202 017 A1

Description

FIELD

[0001] The present disclosure is related to the field of processing plastic material through continuous thermocatalytic conversion into fuel products.

BACKGROUND

[0002] The growth of welfare levels in modern society during the past decades has brought a significant increase in the production of all kinds of commodities, which directly or indirectly generate waste. Plastics have been one of the materials with the fastest growth because of their wide range of applications due to versatility and relatively low cost. Since the duration of life of plastic products is relatively small, there is a vast plastics waste stream that reaches each year to the final recipients thereby creating severe environmental hazards. Since the disposal of post-consumer plastics is continuously being constrained by relevant governmental legislations and escalating costs, there is considerable demand for alternatives to disposal or land filling with waste plastics. Such alternatives may include source reduction, reuse, recycling, and recovery of the inherent energy value through waste-to-energy incineration and processed fuel applications. Each of these options potentially reduces waste and conserves natural resources.

[0003] The process of thermolysis (or pyrolysis) is a well-known method of chemical reaction in which a relatively large compound is broken down into molecules due to high temperatures. Such process for converting waste plastic into liquid fuels is generally acknowledged as a convenient way to handle waste plastic, since the cost is manageable, and the final product (liquid fuel) may have properties that are more or less similar to the common petroleum fuels. In addition, the products that are deriving from the thermolysis of plastic provide the advantage of not containing any sulfur, as the petroleum products do, thereby being more environmentally friendly, since sulfur is a known pollutant that also affects the health of the general public. Conventional plants however, that try to convert waste plastic to usable fuel do show some drawbacks, mainly related to the thermal efficiency of the overall process. In detail, in conventional plants for converting plastic to liquid fuel, the process is not continuous, meaning that when a batch of raw material is process through a thermolysis reactor chamber, then the entire operation should stop so as to cool down the reactor and remove any carbon residues. In addition, the various sections of conventional plants (thermolysis reactor, feedstock system, drying apparatus) are not interconnected, thereby each one requiring its own external source of energy to operate, while at the same time a significant amount of heating energy that is produced during each sections operation is lost, thereby resulting in a relatively low thermal efficiency of the overall plant and consequently to questionable quality of the final products.

[0004] It is thus an object of the present disclosure to overcome the aforementioned drawbacks. The described plant for converting plastic raw material into usable fuel is designed and based on a continuous closed operation cycle where each section of the plant interacts with each other in a way which achieves maximum energy efficiency. In addition, due to the arrangement and interconnection of the various individual stations/equipment of the plant, a relatively compact/controllable size of the plant is achieved, thereby allowing the installation of such a plant in a quite fast and precise manner in any workplace. Such arrangement further allows for a continuous thermolysis reaction and a continuous extraction of syngas from the reactor, thus enhancing the efficiency of the overall plant and process.

SUMMARY

[0005] According to aspects of the present disclosure there is provided a plant configured to convert plastic materials into usable fuel, comprising, a feedstock supply system for the storage of the plastic raw material, a material preparatory system for preparing the raw material prior to the conversion, a preheating line for increasing the temperature of the plastic raw material, a thermolysis reactor for processing the plastic raw material, one or more oil condensers that are connected to the material preparatory system and a distillation tower that is connected to the one or moil oil condensers.

[0006] According to aspects of the disclosure, the plant comprises -an oil boiler distillatory that is connected to the thermolysis reactor, and an oil preheating chamber that is connected to the oil boiler distillatory and to the thermolysis reactor.

[0007] According to aspects of the present disclosure, the plant comprises one or more three-phase separators that are connected to the distillation tower, for separating a fluid from the distillation tower to gas, oil and water phases.

[0008] According to aspects of the present disclosure, the material preparatory system comprises at least two drying apparatuses, wherein the raw material is directed towards the at least two drying apparatus at an ambient temperature and wherein the drying apparatus heats the raw material to reach a temperature between 70-90°C, said temperature being regulated by one or more gas valves.

[0009] According to aspects of the disclosure, the material preparatory system further comprises an oxygen extraction apparatus that is connected to the at least two drying apparatus and is configured to receive the raw material at a temperature between 70-90°C, remove the oxygen from the material and increase the temperature of the raw material in the region of 120-140 °C.

[0010] According to aspects of the disclosure the preheating line comprises a plurality of heat exchanging units wherein said plurality of heat exchanging units are arranged in series and comprises a first feeding heat exchanger configured to receive raw material in solid state at a first temperature and a first conveyor heat exchanger that is connected to the first feeding heat exchanger, a second feeding heat exchanger that is configured to guide the plastic material in molten state towards a second conveyor heat exchanger at a second temperature, wherein the first temperature of the solid state is in between 100-160 °C, optionally 120-140°C, and the second temperature of the molten state is between 180-240°C, optionally 200-220 °C.

[0011] According to aspects of the present disclosure, the the thermolysis reactor comprises a reaction chamber for receiving the material after the preheating line, at least one gas burner for producing exhaust gases, an agitating device for agitating, heating and homogenising the plastic material and a carbon rejection device that is connected to the reaction chamber.

[0012] According to aspects of the present disclosure, the thermolysis reactor is provided with an exhaust gases collector that is connected to the at least one gas burner, wherein said exhaust gases exhaust gases are distributed within the reactor through ducts that form one or more heating jackets that surround the reactor and wherein the exhaust gases pass through the agitating device.

[0013] According to aspects of the present disclosure, the oil boiler distillatory comprises at least one gas burner configured to produce exhaust gases for heating the oil boiler and an exhaust gas passage chamber and a syngas passage chamber, wherein the syngas is a synergy of gas resulting from the thermolysis reactor and the oil boiler distillatory.

[0014] According to aspects of the present disclosure, the one or more oil condensers comprise at least two heat exchanging units, a plurality of control valves and a temperature control system wherein the one or more oil condensers are designed such that when the syngas in the oil condensers, they are condensed to a temperature between 150-180°C with the use of water.

[0015] According to aspects of the disclosure, the one or more three-phase separators are in the form of a vessel and comprise: a primary separation section comprising an inlet for receiving a fluid from the distillation tower, wherein when the fluid enters the vessel comes in direct contact with a deflector, thereby causing separation of the fluid to liquid in the form of droplets and gas phase, a gravity section wherein the droplets are separated by gravity means, a coalescing section and a liquid collection section for receiving the liquid that was removed from the gases in the primary, the gravity and the coalescing section.

[0016] According to aspects of the present disclosure, the feedstock supply system comprises at least one feed silo for storing the raw material, a shredder for shredding the raw material into suitable shape and size and a screw conveyor system for transferring the raw material towards the material preparatory system, wherein the at least one feed silo comprises at least one load cell configure to weight the raw material.

[0017] According to other aspects the screw conveyor system comprises a linking mechanism that is designed such that it allows to connect an additional feed silo with additional raw material to be transferred towards the material preparatory system.

[0018] In other aspects of the disclosure, a process of converting plastic raw material to usable fuel comprising the steps of:

- Providing plastic raw material to a feedstock supply system in an ambient temperature
- Deducting the humidity from the plastic material through heat recovery via a drying apparatus and heating the plastic to a temperature between 70-90°C
- Removing the oxygen from the plastic material through an oxygen removal apparatus and heating the plastic to a temperature between 120 and 140 °C
- Preheating the raw material through heat recovery to a pre-defined temperature via a preheating line, thereby creating a molten plastic
- Heating the molten plastic into a thermolysis reactor thereby modifying its state to gaseous.

[0019] According to aspects of the disclosure the process comprises the steps of transferring syngas that is derived from the thermolysis reactor to an oil preheating chamber and transferring syngas that is derived from an oil boiler distillatory to an oil preheating chamber.

[0020] According to aspects of the disclosure the process comprises transferring the syngas that is derived both from the thermolysis reactor and the oil boiler distillatory from the oil preheating chamber to at least two drying apparatuses.

[0021] According to aspects of the disclosure the process comprises the step of transferring syngas from the at least two drying apparatuses to at least one oil condensers and transferring of the syngas from the at least two oil condensers to a 3-phase separator.

[0022] According to aspects of the disclosure the process comprises the steps of

- transferring exhaust gases from an oil boiler distillatory to an exhaust gases collector of a thermolysis reactor,
- transferring the exhaust gases from the exhaust gases collector of the thermolysis reactor to a preheating line, transferring the exhaust gases from the preheating line to an oxygen extraction apparatus.

[0023] According to aspects of the disclosure the process comprises the step of rejecting carbon residues via a carbon rejecting system.

[0024] Dependent embodiments of the aforementioned aspects of the disclosure are given in the dependent claims and explained in the following description, to which the reader should now refer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Aspects of an embodiment will be described in reference to the drawings, where like numerals reflect like elements:

- Figure 1 shows a process flowchart of a continuous thermolysis plastic-to-fuel conversion plant according to present concept
- Figures 1a, 1b, 1c are three enlarged views of three successive parts of Figure 1
- Figures 2 shows the main components of the plant according to the present concept
- Figure 3 shows an overview of the exhaust gas flow according to the present concept
- Figure 4 shows an overview of the syngas flow according to the present concept

DETAILED DESCRIPTION

[0026] An embodiment of the plant according to aspects of the disclosure will now be described with reference to Figures 1-4. Although the plant and the process of converting plastic raw material to usable fuel described with reference to specific examples, it should be understood that modifications and changes may be made to these examples without going beyond the general scope as defined by the claims. In particular, individual characteristics of the various embodiments shown and/or mentioned herein may be combined in additional embodiments. Consequently, the description and the drawings should be considered in a sense that is illustrative rather than restrictive. The Figures, which are not necessarily to scale, depict illustrative aspects and are not intended to limit the scope of the disclosure. The illustrative aspects depicted are intended only as exemplary.

[0027] The term "exemplary" is used in the sense of "example," rather than "ideal." While aspects of the disclosure are amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit aspects of the disclosure to the particular embodiment(s) described. On the contrary, the intention of this disclosure is to cover all modifications, equivalents, and alternatives falling within the scope of the disclosure.

[0028] Various materials, methods of construction and methods of fastening will be discussed in the context of the disclosed embodiment(s). Those skilled in the art will recognize known substitutes for the materials, construction methods, and fastening methods, all of which are contemplated as compatible with the disclosed embodiment(s) and are intended to be encompassed by the appended claims.

[0029] As used in this disclosure and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the content clearly dictates otherwise. As used in this disclosure and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

[0030] Throughout the description, including the claims, the terms "comprising a," "including a," and "having a" should be understood as being synonymous with "comprising one or more," "including one or more," and "having one or more" unless otherwise stated. In addition, any range set forth in the description, including the claims should be understood as including its end value(s) unless otherwise stated. Specific values for described elements should be understood to be within accepted manufacturing or industry tolerances known to one of skill in the art, and any use of the terms "substantially," "approximately," and "generally" should be understood to mean falling within such accepted tolerances.

[0031] When an element or feature is referred to herein as being "on," "engaged to," "connected to," or "coupled to" another element or feature, it may be directly on, engaged, connected, or coupled to the other element or feature, or intervening elements or features may be present. In contrast, when an element or feature is referred to as being "directly on," "directly engaged to," "directly connected to," or "directly coupled to" another element or feature, there may be no intervening elements or features present. Other words used to describe the relationship between elements or features should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.).

[0032] Spatially relative terms, such as "top," "bottom," "middle," "inner," "outer," "beneath," "below," "lower," "above," "upper," and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the drawings. Spatially relative terms may be intended to encompass different orientations of a device in use or operation in addition to the orientation depicted in the drawings. For example, if the device in the drawings is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0033] Although the terms "first," "second," etc. may be used herein to describe various elements, components, regions, layers, sections, and/or parameters, these elements, components, regions, layers, sections, and/or parameters should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer, or section from another region, layer, or section. Thus, a first element, component, region, layer, or section discussed herein could be termed a second element, component, region, layer, or section without departing from the teachings of the present disclosure .

[0034] Figure 1 and partial views 1a, 1b, 1c of the same Figure 1 illustrate the various stations of the plant for converting plastic material to usable fuel. The plant, according to a first embodiment of the disclosure, comprises a feedstock supply system that may comprise two or more feed silos (004, 011), a material preparatory system for preparing the raw material prior to the conversion, wherein the material preparatory system may comprise at least two drying apparatuses (101, 104), a preheating line (201, 202) for increasing the temperature of the plastic raw material, a thermolysis reactor (301) for processing the raw material, one or moil oil condensers (501, 502) that are connected to the material preparatory system and more specifically to the at least two drying apparatuses (101, 104) and a distillation tower (511, 513) that is connected to the one or more oil condensers (501, 502). In examples, the plant may further comprise an oil boiler distillatory (401) that is connected to the thermolysis reactor (301) and an oil preheating chamber (307) that is connected to the oil boiler distillatory (401) and to the thermolysis reactor (301). Additionally, the plant may also comprise one or more three-phase separators (512, 514) that are connected to the distillation tower (511, 513) and their purpose is to separate the fluid to gas and oil and water phase. Such arrangement and interconnection of the various components of the conversion plant is advantageous since it provides a continuous closed operation cycle where each section of the plant interacts with each other, thereby achieving the maximum possible energy efficiency.

[0035] In an embodiment, the feedstock supply system may also comprise a shredding device and a screw conveyor. The plastic raw material in its initial shape which may be cylindrical, or sheet shaped etc., is transferred to the shredding device where the relatively large parts are shredded and thus minimized to suitable shape and size. In an example, an overband magnet may also be used to separate the any metal residues from the raw material in an effective and quick manner. Upon separation of the metal components the shredding device forms the plastic material preferably in cylindrical shaped particles (’spheres’) with a maximum diameter of 10mm. Afterwards, such spheres are guided through conveyors to holding silos where they are stored before being fed to the feed silos.

[0036] The plastic materials that are suitable for the conversion according to the present disclosure may be, but not limited to, PE (polyethylene), PET (polyethylene terephthalate), HDPE (high density polyethylene), LDPE (low density polyethylene), PP (polypropylene), PS (polystyrene), ABS (acrylonitrile-butadiene-styrene copolymer). In an example, the most preferred feedstock from the above list of materials for the production of liquid hydrocarbons are the PE, PP and PS thermoplastics which with the addition of thermosetting plastics, wood, and paper to the feedstock results to the formation of carbonous substances and lowers the rate and yield of liquid products. This happens because the thermolysis products are directly related to the chemical composition and chemical structure of the plastics, since the chemical composition of the feedstock affects the thermolysis process. It has to be noted, that is of significant importance if the plastic feedstock contains PVC, since the PVC thermolysis the resulting products may contain HCl that is found to be hazardous for the fuels. In that case wherein the feedstock comprises PVC the plant should also comprise a re-treatment system to remove Hcl from the resulting pyrolysis products. The thermolysis products may be grouped as petroleum gases, petrol, kerosene, diesel and WAX ($>C_{50}$). The above-mentioned fuels may contain hydrocarbon group with different carbon chain lengths as given in below Table1. However, it has to be contemplated that there are also other ways to describe the hydrocarbons such as boiling range, phase of products at room temperature etc.

Table 1. Hydrocarbon range in commercial fuels

Fuels	LPG	Petrol	Kerosene	Diesel	Heavy Fuel oil
Hydrocarbons	C_1 to C_4	C_5 to C_{10}	C_{10} to C_{16}	C_{14} to C_{20}	C_{20} to C_{70}

[0037] In embodiments of the present disclosure, the feedstock supply system may comprise two or more feed silos.

A different type of plastic may be stored in each silo, such as but not limited to: PE (polyethylene), PET (polyethylene terephthalate), HDPE (high density polyethylene), LDPE (low density polyethylene), PP (polypropylene), PS (polystyrene), ABS (acrylonitrile-butadiene-styrene copolymer) or a mixture of the above. In that way, the plant has the flexibility to select a percentage of each type of plastic each time and make a mixture of different types depending on the availability of raw materials and the target parameters set for the final products, the desired "recipe" is selected each time to produce high quality liquid fuel in the best and most efficient way for the operation of the plant. In an example, feedstock is loaded into a hopper (001) and is led for storage via a screw conveyor network in weighing silos (004, 011, 016, ...). The structured way of connecting the screw conveyors (010, 020, ...), allows the addition of storage silo (011, 016...) without requiring changes to the overall mechanical equipment, making the feedstock supply system easily expandable from, for example 1 to 9 silos. Each silo (004, 011, 016, ...) may be mounted on load cells (005, 012, 018, ...). At the bottom of each silo, for example at its outlet, there may be a proportional flow valve (006) which is configured to control the flow of raw material coming out of the silo. Additionally, under each silo there may be located a conveyor link (007, 042). In detail, the material coming out of the silo is inserted in the conveyor link (007). Conveyor link is designed to have appropriate ports where screw conveyors (009, 010, 020, ...) can be connected and through them material to be directed to the next station of the plant. The construction of the conveyor link (007) is such that it allows the connection of screw conveyors between the silos (009, 010, 020, ...) so that a network of screw conveyors can be created. In this way, the mixing of the raw materials is achieved depending on the percentage of raw material from each silo, for the completion of the recipe. Maintenance of the overall equipment is also facilitated since it is not required to interrupt the entire production process.

[0038] In embodiments, a material preparatory system is used for preparing the raw material prior to the thermolysis reaction. The purpose of this system is to deduct humidity and oxygen from the plastic material and calculate the quantity of the material that will be further processed. In an example, the material preparatory system comprises at least two drying apparatus (101, 104). Feedstock is guided through a screw conveyor network (010, 020,) from the feed silos (004, 011,...) to the dryers (101, 104). Said dryers may be mounted on load cells that ensure the precision of the quantity of the material to be processed. The dryers may be of cylindrical shape and each of them may comprise a screw conveyor for filling and recirculating the plastic material. In addition, the dryers (101, 104) may also comprise one or more gas heat exchangers for diffusing relatively hot air to the plastic material during the drying process. In an example, the drying apparatus (101, 104) may be designed such that they comprise two heating jackets thereby allowing the gases to pass and the necessary heat to be transferred to the plastic material. The plastic material enters the at least two drying apparatus at an ambient temperature and is heated to a temperature between 70-90°C. In an embodiment, this preheating of the material is achieved by heat recovery the recirculation of syngas that are coming from a thermolysis reactor (301) and an oil boiler distillatory as it will be described later in that specification. In that case, through paths/ducts and specially designed proportional gas valves (122, 123) syngas gases are guided to heating jackets that surround each drying apparatus thereby increasing the temperature of the material to the desired range. As already mentioned, a jacket for the syngas is coming from the thermolysis reactor (301) and another jacket is coming from an oil boiler distillatory. In an example, the plant may also comprise an oil preheating chamber (307) that is connected to the thermolysis reactor (301) and the oil boiler distillatory (401). In that case, syngas that is coming from an oil preheating chamber (307), where energy has been recovered (from ~400°C reduced to ~ 330°C) and their temperature when they enter the dryer heating jacket is ~ 320°C, while when exiting of it ~230°C is also guided to the drying apparatus. The difference in inlet-outlet temperature Δt of the syngas, is the recovered energy transferred to the plastic raw material. The recovered energy Er depends on the flow of the plastic raw material and its temperature difference in the dryers. According to the described arrangement, the below calculation can be derived:

$$E_r = Q_{raw\ material} * \Delta t_{raw\ material}$$

$$\Delta t = t_{in} - t_{out}$$

<u>*where,*</u>

Er= Energy recovery
Q= Material flow / h
Δt = Temperature difference
t_{in} = Inlet temperature
t_{out} = Output temperature

The setting of the desired temperature of the plastic raw material at 70°C - 90°C and the humidity level <1%, is achieved by the automatic control of special proportional gas valves (122, 123, ...). The flow of the syngas is regulated through the valves, depending on the current operating conditions.

[0039] Additionally, the concentrates resulting from the temperature reduction of the syngas coming from the Thermolysis reactor (301), are led to the olefins tank (311) for further processing.
The condensates resulting from the temperature reduction of the syngas coming from the Oil Boiler distillatory (401), are transferred to a C20 - C50 condensate storage tank. In a preferred embodiment of the present disclosure, the plant comprises two dryers (101, 104). In that specific embodiment, when the plastic raw material is prepared in the first dryer (101), then it feeds the next stage of the process. While the first dryer (101) feeds the next stage, the second dryer (104) prepares the plastic raw material. Once the first dryer (101) is empty, then the supply of the next stage is done by the second dryer (104) and in the first dryer (101) the preparation of the material begins.

[0040] In an embodiment, the material preparatory system comprises an oxygen extraction apparatus (112) that is connected to the at least two drying apparatus and is configured to receive the raw material at a temperature between 70-90°C, remove the oxygen from the material and increase the temperature of the raw material in the region between 120 and 140 °C. When the process of preparing the material in the dryers is completed, material is at a temperature of 70°C - 90°C and humidity level < 1%. Then the material is led through screw conveyors (107, 109, 111) to the next stage and enters the oxygen extraction apparatus (112). The oxygen extraction apparatus may comprise a rotating cylindrical chamber. Such apparatus (112) may contain suitably designed diffusers with which the plastic raw material is evenly diffused in the space. The increasing of material temperature from 70°C to 90°C up to the region of 120°C to 140°C and the removal of oxygen from the material, may be achieved by heat recovery from the recirculation of exhaust gases, which are coming from the pre-heating line (201). Exhaust gases are led through specific paths into the apparatus for oxygen extraction. By the exhaust gases diffusion, oxygen is removed and with proportional exhaust gases valves (116, 117) achieved full temperature control of material.

[0041] In an embodiment, the preheating line (201) may comprise an array of heat exchangers with corresponding screw conveyors. Said heat exchangers may be distinguished to feeding heat exchangers IN (201), conveyor heat exchanger IN (202), feeding heat exchanger OUT (203) and conveyor heat exchanger OUT (204). A heat exchanger group that includes the above modules may be called a unit. In a preferred embodiment the preheating line may comprise 3 three said units. In an example, plastic material is introduced into the feeding heat exchanger IN (201) in solid state and at a temperature of 120°C - 140°C. As it passes through the conveyor heat exchanger IN (202), feeding heat exchanger OUT (203), conveyor heat exchanger OUT (204), its temperature increases. Passing through all three (3) units of the preheating line the plastic material has become molten and its temperature at the exit from the preheating line is at 200°C - 220°C. In an example, the exchangers may comprise sensors for measuring the temperature at the inlet and outlet of the material and at the inlet and outlet of the exhaust gases. In addition, each conveyor heat exchanger is suitable for gas and solid material. The increase in the temperature of the material is achieved by recovering the heat from the recirculation of the exhaust gases, which come from the thermolysis reactor (301) and the oil boiler distillatory (401). In examples, at the input and the output of the conveyor heat exchangers there may be located a first linking mechanism with which the conveyor heat exchangers are connected to each other, and the material is transferred and a second linking mechanism for the exhaust gases, with which the exhaust gases are routed and the heating jackets of the conveyor heat exchangers are connected. Such configuration is advantageous since it allows the raw material to increase its temperature in an energy efficient manner since no external power source is required because of the heat recovery from the exhaust gases. In addition, scalability and overall maintenance of the overall system is enhanced since conveyor heat exchangers may be added or maintained without the need for modifications to the other equipment.

[0042] In an embodiment, the thermolysis reactor comprises a reaction chamber (301) for receiving the material after the preheating line, at least one gas burner (302) for producing exhaust gases, an agitating device (303) for heating the plastic material and a carbon rejection device (304) that is connected to the reaction chamber. When the process of preparing the material in the preheating line section is completed, material has become molten with temperature about 220°C. Then the material is led to the thermolysis reactor (301). It has to be noted that molten plastic is continuously fed to the reactor, thereby ensuring uninterrupted operation of the entire plant. The reactor chamber where the thermolysis takes place may be made of stainless steel to ensure durability. It may be arranged horizontally and may have a semicircular shape. The at least one gas burner (302), which may be preferably two, are used to create the required temperature for the heating distributors, in order to achieve the optimal diffusion of the exhaust gases. They may preferably be mounted on one side of the reactor chamber and direct the exhaust gases through specific paths to the reactor where the thermolysis reaction of the plastic takes place. Power of the burners is proportional to a wide range and a closed loop air / fuel ratio control is performed, to achieve maximum efficiency and low NOx levels. It has to be noted that these gas burners (302) are capable of receiving variable fuels. Depending on availability, natural gas or liquefied petroleum gas (LPG) can be used as the main fuel and non-condensable gases as supplementary fuel. Non-condensable gases are stored in a tank where, depending on the stock, the filling rate of the fuel mixture is automatically calculated. In this way, the basic fuel is saved and the non-condensable gases are utilized. In an example, the thermolysis reactor may also comprise an exhaust gases collector (305) that is connected to the at least one gas burner (302), wherein said exhaust gases exhaust gases are distributed within the reactor through ducts that form one or more heating jackets that surround the reactor (301). Through the exhaust gas collector (305), exhaust gases are collected by reactor heating jackets that surround the reactor (301). In each heating jacket, there may be a proportional flow control valve (312) at the exhaust outlet. By controlling the flow of exhaust gases through each heating jacket, a uniform distribution of temperature is achieved on the walls of the outer surface of the reactor, achieving maximum temperature absorption by the material that comes in contact with them. In an example, the thermolysis reactor comprises a reactor screw assembly. At the exhaust outlet of the screw assembly, there is a proportional valve (312) to regulate the exhaust flow. By controlling the exhaust gas flow, the maximum thermal energy efficiency in the reactor core is achieved by adapting the flow to the current operating conditions. In addition, exhaust gases that are collected from the oil boiler distillatory and through the proportional flow control valve (406) at the exhaust outlet, the necessary vacuum in the combustion chamber of the oil boiler distillatory is automatically regulated.

[0043] In embodiments, the agitation device (303) may comprise screws in the form of helical ducts of different diameters and opposite direction which are configured to agitate and heat the material in the reactor core using the exhaust gases. In addition, scrapers that are fitted around the screws, detach and transport any residues (for example coke formation and carbonized products) that may be created during the thermolysis process and accumulate on the walls of the reactor, to a carbon black reject mechanism (304) through a fully automated process. In an example, the carbon reject system may be mounted on the bottom of the reactor chamber. Through special isolation valves, the discharge of residues from the reactor chamber is without oxygen inflow into the reactor.

[0044] In embodiments, (molten) plastic enters the thermolysis reactor, preferably at a temperature of 220°C. Its temperature begins to rise using the heat of the exhaust gases which may be led to the thermolysis reactor through two different ways: Exhaust gases are led to the outside of the reactor through ducts that form three heating jackets. In each heating jacket, there may be a proportional flow control valve (312) at the exhaust outlet. By controlling the flow of exhaust gases through each heating jacket, a uniform distribution of temperature is achieved on the walls of the outer surface of the reactor, achieving maximum temperature absorption by the material that comes in contact with them. The controlling of the exhaust temperature its constant value of the three (3) heating jackets, ensures maximum absorption of temperature by the material from the total surface of reactor. In an example, the exhaust gases are led inside the thermolysis reactor through two (2) helical paths of different diameters and opposite direction, forming two (2) screws where one is placed inside the other. By rotating the screw assembly (303), the larger diameter screw located on the outer layer pushes the material to always move in the opposite direction from the inner screw. In this way two flow streams of the material are formed, where with the repeated circulation of the flow, the heat is transferred directly and evenly throughout the material, making it completely homogenized. As the exhaust gas passes through the screw assembly (303), heat is transferred to the material in the reactor core, increasing the heat transfer rate and therefore the efficiency of the reactor.

[0045] In an embodiment, the temperature inside the reactor (301) reaches to a range from 370°C to 425°C. At this temperature, the plastic becomes gaseous. The reaction of the plastic at this temperature causes the plastic carbon chain lengths to randomly break into various lengths. The pressure inside the reactor may rise to 3 bar. The syngas resulting from the thermolysis reaction pass through specially designed sections which contain electrical resistors. In this way the temperature at these points is at the desired level to achieve gasification and any small particles that have resulted from the thermolysis reaction but have not yet been gasified. Syngas exits the reactor (301) and are led through a piping network with proportional valves (308, 309) to a catalyst chamber (306). The catalyst chamber (or converter) (306) comprises metal plates with channels or grooves that may be placed crosswise so that the gases are directed through them to maximize their contact time with them. These channels typically have a height in millimeters and catalyst thickness measured in microns. The grooves may be coated with a suitable catalyst and can be arranged so that exothermic and endothermic reactions take place in alternative channels. Heat transfer is by conduction from the exothermic to the endothermic region. The advantages of this catalyst converter over conventional reactors are since the heat transfer rates (through conduction) are very high and the endo catalytic diffusion resistances are minimal. The catalyst ensures that the final fuel has a carbon chain distribution in the C8-C25 range and peaks at C16 (ketone). The gases resulting from this process are led to the Preheating Oil chamber (307).

[0046] The preheating oil chamber (307) is a heat exchanger in which condensation is achieved through energy recovery. With this mode of operation and by recovering the energy present in the syngas, the fuel is separated from the syngas that come from the Thermolysis Reactor (301) and the Oil Boiler distillatory (401). The preheating oil chamber may comprise a syngas passage chamber (different chamber for syngas from the Thermolysis Reactor (301) and different chamber for syngas from the Oil Boiler distillatory (401)) and a fuel passage chamber for syngas coming from an olefin tank (311) and is used as cooling medium of the system. The type of condensate that will result from the syngas depends on the rate of energy recovery that will take place. The syngas from the Thermolysis reactor (301) and the Oil Boiler distillatory (401) enter, each in a different chamber, the preheating oil chamber (307) at a temperature of approximately 400°C. The length of the carbon chain of the condensate that will occur, depends on their outlet temperature from the preheating oil chamber (307). The inlet-outlet temperature difference Δt of the syngas, is the recovered energy transferred to the fuels. The recovered Er energy depends on the flow and temperature of the fuels in the preheating oil chamber (307).

[0047] For optimal efficiency, automatic system operation and syngas condensate quality control, the flow and temperature of the fuel must be fully controlled. For the control of the flow and the recirculation of the fuel there may be a proportional three-way valve and for the temperature control of the fuel there is a heating-cooling temperature control system, depending on the system requirements. The following calculation may be considered:

$$Energy\ recovery = Flow * Temperature\ difference$$

$$E_r = Q_{raw\ material} * \Delta t_{raw\ material}$$

$$\Delta t = t_{in} - t_{out}$$

where,

Er= Energy recovery

Q= Material flow / h

Δt = Temperature difference

t_{in} = Inlet temperature

t_{out} = Output temperature

from the above arises that:

$$Flow_{Syngas} * Temperature\ difference_{Syngas} = Flow_{Crude\ Heavy\ oil} * Temperature\ difference_{Crude\ Heavy\ oil}$$

$$Q_{Syngas} * \Delta t_{Syngas} = Q_{Crude\ Heavy\ oil} * \Delta t_{Crude\ Heavy\ oil}$$

[0048] After heat recovery, the fuel exits the preheating oil chamber (307) at approximately ~230°C and is forwarded to the Oil Boiler distillatory (401) for further processing. Concentrates from syngas constitute WAX (>C_{50}).

[0049] In conclusion, the operation of the above system is based on the controlled cooling of the fuels to recover energy from the syngas. With the above-described configuration and process quality control of WAX >C_{50} concentrates is achieved while the increase of the temperature of the fuel from ~50°C to ~230°C leading to the Oil Boiler distillatory (401), thus saving the energy that the Oil Boiler distillatory will need to further gasify the condensates. The syngas with reduced temperature, through a network of piping are led to the Dryers of the Material Preparatory section for further energy recovery.

[0050] In an embodiment, the fuel entering the Oil Boiler distillatory (401) may have a temperature of 220°C - 230°C. A gas burner is used to increase the temperature. The power of the burner is proportional to a wide range and a closed loop air / fuel ratio control is performed, in order to achieve maximum efficiency and low NOx levels.

[0051] A key feature of the gas burner is its multi fuel function. Depending on availability, natural gas or liquefied petroleum gas (LPG) can be used as the main fuel and non-condensable gases as supplementary fuel. Non-condensable gases are stored in a tank where, depending on the stock, the filling rate of the fuel mixture is automatically calculated. In this way, the basic fuel is saved, and the non-condensable gases are utilized.

[0052] The Oil Boiler distillatory (401) may comprise a pair of chambers designed for maximum absorption of thermal energy. The pressure inside the reactor may reach six (6) bar. The syngas resulting from this process are led to the preheating oil chamber (307), whereby the procedure described above, the WAX (>C_{50}) contained in the syngas is concentrated and separated. Using software, the degree of performance is calculated and when it drops below a certain level, the regeneration process begins. At the bottom of the distillatory (401) there is a valve where when it opens, residues of WAX (>C_{50}) are rejected. During the regeneration process, the supply of the Oil Boiler distillatory (401) is interrupted, while the burner operates at its minimum power in order to maintain the temperature of Boiler distillatory and facilitate the elimination of residues. After the end of this regeneration stage, all parts of the unit are automatically put into production process mode. Operation of the reactor (301) is continuous. Reactor is mounted on load cells so that it is automatically checked for its continuous feeding with material from the Preheating Line section. Using software, the degree of performance is calculated and when it drops below a certain level, the regeneration process begins. When the carbon residues reach a certain level, then automatically all parts of the unit are put into proper operation so that the reactor enters regenerative mode. At this stage the carbon black reject system (304) is activated, and the residues generated by the thermolysis process are discarded from the reactor (301). At the end of this reactor regeneration phase, all parts of the unit are automatically put into production process mode. The regeneration process does not require the reduction of the reactor (301) temperature, so the accumulated energy in the reactor mass remains and thus the recovery of its energy is not required to continue the production process. In this way the regeneration time of the reactor is limited only to the disposal of carbon residues without the loss of its thermal energy.

[0053] In embodiments, the oil condensers (501, 502) may comprise two (2) vessels with heat exchangers, proportional valves, and cooling temperature control system, depending on the system requirements. Syngas is led to oil condensers through a network of pipes and valves, where they are condensed using cooling water. By controlling the flow of refrigerant through analog valves, temperature of the condensates is regulated (~150C' - ~180C°).

[0054] In an embodiment the tower distillation (511, 513) separates the light fractions from the concentrates. Depending on the temperature of the syngas coming from the oil condensers (501, 502) and the temperature of the refrigerant, type of light fractions that will occur varies. The gas rises level through the tower. As the gases rise, their temperature drops, and some hydrocarbons begin to condense. Each fraction condensed to a certain level contains hydrocarbon molecules with a similar number of carbon atoms.

[0055] In an example, the mixture of oil, water and gas resulting from this step is led to one or more 3-phase separators (512, 514) that may be arranged in series. The 3-phase separators (512, 514) may comprise:

- a primary separation section comprising an inlet for receiving a fluid from the distillation tower, wherein when the fluid enters the vessel comes in direct contact with a deflector, thereby causing separation of the fluid to liquid in the form of droplets and gas phase.
- a gravity section wherein the droplets are separated by gravity means
- a coalescing section
- a liquid collection section for receiving the liquid that was removed from the gases in the primary, the gravity and the coalescing section. The primary separation section is used to separate the main portion of free liquid in the inlet stream. The liquid enters the vessel through an inlet and immediately strikes a deflector. Sudden impact causes the initial separation of liquid and gas. The secondary or gravity section, is designed to use the force of gravity to enhance separation of entrained droplets. The coalescing section utilizes a coalescer or mist extractor. It may be constructed of stainless-steel wire mesh tightly wrapped in a cylindrical shape. The effectiveness of wire mesh depends largely on the appropriate gas velocity range. If the velocity is too high, the liquids knocked out will be re-entrained. If the velocity is low, the vapour just drifts through the mesh element without the droplets impinging and coalescing. The liquid collection section acts as receiver for all liquid removed from gas in the primary, secondary, and coalescing section. In an example, in a 3-phase separator, an inlet flap device is used in order to gradually reduce the inlet momentum and evenly distribute the gas phase across the vessel diameter.

[0056] In an embodiment, the previously described plant can operate a process of converting plastic raw material to usable fuel that is comprising the steps of:

- Providing plastic raw material to a feedstock supply system (011) in an ambient temperature
- Deducting the humidity from the plastic material via a drying apparatus (101) and heating the plastic to a temperature between 70-90°C
- Removing the oxygen from the plastic material through an oxygen removal apparatus and heating the plastic to a temperature between 120 and 140 °C
- Preheating the raw material to a pre-defined temperature via a preheating line (210, 203), thereby creating a molten plastic
- Heating the molten plastic into a thermolysis reactor (301) thereby modifying its state to gaseous.

[0057] In another example, the process may also comprise transferring syngas that is derived from the thermolysis reactor (301) to an oil preheating chamber (307) and transferring syngas that is derived from an oil boiler distillatory to an oil preheating chamber (307). In another example the process may further comprise the step of transferring the syngas that is derived both from the thermolysis reactor (301) and the oil boiler distillatory (401) from the oil preheating chamber (307) to at least two drying apparatuses (101, 104). In an example the process may comprise the step of transferring syngas from the at least two drying apparatuses to at least one oil condensers and transferring of the syngas from the at least two oil condensers to a 3-phase separator. In another example, the process may also comprise the steps in the following order:

- Transferring exhaust gases from an oil boiler distillatory (401) to a thermolysis reactor (301)
- Transferring the exhaust gases from the thermolysis reactor (301) to a preheating line (201, 202)
- Transferring the exhaust gases from the preheating line (401) to an oxygen extraction apparatus (112).

[0058] Such process is advantageous since it allows the separation and storage of plastic raw materials in different silos (004, 011, ...) depending on the type and quality of the plastic, and allows the percentage reception of raw material from each silo in order to complete the recipe. In addition, the recovery of energy from the produced syngas and from the exhaust gases of the burners, enhances the unit efficiency. It has to be noted that according to the described process and arrangement, syngas is continuously produced and subsequently removed from the reaction chamber of the thermolysis reactor. Further, due to the slight temperature difference between the liquid plastic material entering the reactor and the temperature at which the heat treatment reaction takes place and the design of the screw assembly which provides direct and uniform heat transfer to the material from the core of the reactor and at the same time its homogenization, the residence time of the raw material in the reactor is reduced to the minimum. Last, through the light fractions distillation tower and the distillates collection from different points of the unit of the present disclosure, the final product may be divided into three (3) categories: light, medium and heavy distillates, thereby resulting in a stable and controlled quality of the final products which come from a lower temperature reaction, with or without the use of catalysts.

[0059] It should be noted that the above embodiments are only for illustrating and not limiting the technical solutions of the present disclosure. Although the present disclosure has been described in detail with reference to the above embodiments, those skilled in the art should understand that any modifications or equivalent substitutions of the present disclosure are intended to be included within the scope of the appended claims.

[0060] Although the present disclosure herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present disclosure.

[0061] It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the appended claims.

Reference numerals

[0062]

001	Hopper
002	Vertical screw conveyor
003	Conveyor outlet
004, 011, 016, 019, 025, 030	Feed silo
005, 012, 018, 021, 026, 031	Load cells
006, 013, 017, 022, 027, 032	Proportional flow valve
007, 008, 042, 043, 023, 028, 033, 037, 039, 108, 110, 113	Conveyor link
009, 010, 015, 020, 024, 029, 034, 035, 036, 038, 040, 041, 107, 109, 111, 114	Screw conveyor
101, 104	Dryer
102, 103, 105, 106, 115, 121	Ventilation fan
112	Apparatus for oxygen extraction
116, 117, 119, 120, 312, 406	Proportional flow control valve
309, 403	Proportional diaphragm seat flow valve
122, 123, 124, 125 308, 404	Proportional gas ball valve
126, 127, 128, 129 503, 504, 505, 506, 507, 508	Pneumatic gas ball valve
201, 203, 205, 207, 209, 211,	Feeding Heat exchanger
202, 204, 206, 208, 210, 212, 213, 214	Conveyor Heat exchanger
301	Thermolysis reactor chamber

(continued)

302	Thermolysis reactor Gas burner
303	Thermolysis reactor material agitator
304	Thermolysis reactor Carbon black reject system
305	Thermolysis reactor exhaust gases collector
306	Catalyst chamber
307	Preheating oil chamber
311	Olefin tank
401	Oil Boiler distillatory
402	Oil Boiler distillatory gas burner
310, 405	Safety relief valve
501, 502	Condensing vessel
130, 131, 509, 510	Accumulator tank
511, 513	Tower distillation
512, 514	3-phase separator

Claims

1. A plant configured to convert plastic materials into usable fuel, comprising:

- A feedstock supply system for the storage of the plastic raw material
- A material preparatory system for preparing the raw material prior to the conversion
- A preheating line (201) for increasing the temperature of the plastic raw material
- A thermolysis reactor (301) for processing the plastic raw material
- One or more oil condensers (501, 502) that are connected to the material preparatory system,
- A distillation tower (511, 513) that is connected to one or moil oil condensers (501, 502).

2. The plant according to claim 1 comprising:

- An oil boiler distillatory (401) that is connected to the thermolysis reactor (301)
- An oil preheating chamber (307) that is connected to the oil boiler distillatory (401) and to the thermolysis reactor (301)

3. The plant according to claims 1 or 2 comprising one or more three-phase separators (512, 514) that are connected to the distillation tower (511, 513).

4. The plant according to claims 1-3 wherein the material preparatory system comprises at least two drying apparatuses (101, 104), wherein the raw material is directed towards the at least two drying apparatus (101, 104) at an ambient temperature and wherein the drying apparatus heats the raw material to reach a temperature between 70-90°C, said temperature being regulated by one or more gas valves (122, 123).

5. The plant according to claim 2 wherein the material preparatory system further comprises an oxygen extraction apparatus (112) that is connected to the at least two drying apparatus and is configured to receive the raw material at a temperature between 70-90°C , remove the oxygen from the material and increase the temperature of the raw material up to 120-140 °C.

6. The plant according to claims 1 or 2 wherein the preheating line comprises a plurality of heat exchanging units wherein said plurality of heat exchanging units are arranged in series and comprises

- a first feeding heat exchanger (201) configured to receive raw material in solid state at a first temperature and

a first conveyor heat exchanger (202) that is connected to the first feeding heat exchanger,
- a second feeding heat exchanger (203) that is configured to guide the plastic material in molten state towards a second conveyor heat exchanger (204) at a second temperature,
wherein the first temperature of the solid state is in between 100-160 °C, optionally 120-140°C, and the second temperature of the molten state is between 180-240°C, optionally 200-220 °C.

7. The plant according to any of the preceding claims wherein the thermolysis reactor comprises

- a reaction chamber (301) for receiving the material after the preheating line
- at least one gas burner (302) for producing exhaust gases,
- an agitating device (303) for agitating, heating and homogenising the plastic material
- a carbon rejection device (304) that is connected to the reaction chamber

8. The plant according to claim 7, when dependent on claim 2, wherein the thermolysis reactor (301) is provided with an exhaust gases collector (305) that is connected to the at least one gas burner (302),
wherein said exhaust gases exhaust gases are distributed within the reactor through ducts that form one or more heating jackets that surround the reactor (301) and wherein the exhaust gases pass through the agitating device (303)

9. The plant according to any of the preceding claims wherein the oil boiler distillatory comprises

- at least one gas burner (402) configured to produce exhaust gases for heating the oil boiler,
- an exhaust gas passage chamber
- a syngas passage chamber, wherein the syngas is a synergy of gas resulting from the thermolysis reactor and the oil boiler distillatory

The plant according to claims 1-9 wherein the one or more oil condensers (501, 502) comprise at least two heat exchanging units, a plurality of control valves and a temperature control system wherein the one or more oil condensers are designed such that when the syngas in the oil condensers, they are condensed to a temperature between 150-180°C with the use of water.

10. The plant according to any of the preceding claims wherein the one or more three-phase separators are in the form of a vessel and comprise:

- a primary separation section comprising an inlet for receiving a fluid from the distillation tower, wherein when the fluid enters the vessel comes in direct contact with a deflector, thereby causing separation of the fluid to liquid in the form of droplets and gas phase.
- A gravity section wherein the droplets are separated by gravity means
- A coalescing section
- A liquid collection section for receiving the liquid that was removed from the gases in the primary, the gravity and the coalescing section

11. The plant according to claims 1-11 wherein the feedstock supply system comprises at least one feed silo (004, 011) for storing the raw material, a shredder for shredding the raw material into suitable shape and size and a screw conveyor system for transferring the raw material towards the material preparatory system, wherein the at least one feed silo comprises at least one load cell configure to weight the raw material.

12. The plant according to claim 12 wherein the screw conveyor system comprises a linking mechanism that is designed such that it allows to connect an additional feed silo with additional raw material to be transferred towards the material preparatory system.

13. A process of converting plastic raw material to usable fuel comprising the steps of:

- Providing plastic raw material to a feedstock supply system (011) in an ambient temperature
- Deducting the humidity through heat recovery from the plastic material via a drying apparatus (101) and heating the plastic to a temperature between 70-90°C
- Removing the oxygen from the plastic material through an oxygen removal apparatus and heating the plastic to a temperature between 120-140 °C
- Preheating the raw material through heat recovery to a pre-defined temperature via a preheating line (210,

203), thereby creating a molten plastic
- Heating the molten plastic into a thermolysis reactor (301) thereby modifying its state to gaseous.

14. The process of claim 14 comprising

- Transferring syngas that is derived from the thermolysis reactor (301) to an oil preheating chamber (307)
- Transferring syngas that is derived from an oil boiler distillatory to an oil preheating chamber (307)

15. The process of claim 14 or 15 further comprising:

- Transferring the syngas that is derived both from the thermolysis reactor (301) and the oil boiler distillatory (401) from the oil preheating chamber (307) to at least two drying apparatuses (101, 104).

16. The process according to claim 14 comprising:

- Transferring syngas from the at least two drying apparatuses to at least one oil condensers and transferring of the syngas from the at least two oil condensers to a 3-phase separator.

17. The process according to any of claims 14-17 comprising the steps of

- Transferring exhaust gases from an oil boiler distillatory (401) to an exhaust gases collector of a thermolysis reactor (301)
- Transferring the exhaust gases from the exhaust gases collector of the thermolysis reactor (301) to a preheating line (201, 202)
- Transferring the exhaust gases from the preheating line (201, 202) to an oxygen extraction apparatus (112)

18. The process according to any of claims 14-18 comprising the step of rejecting carbon residues via a carbon rejecting system (304).

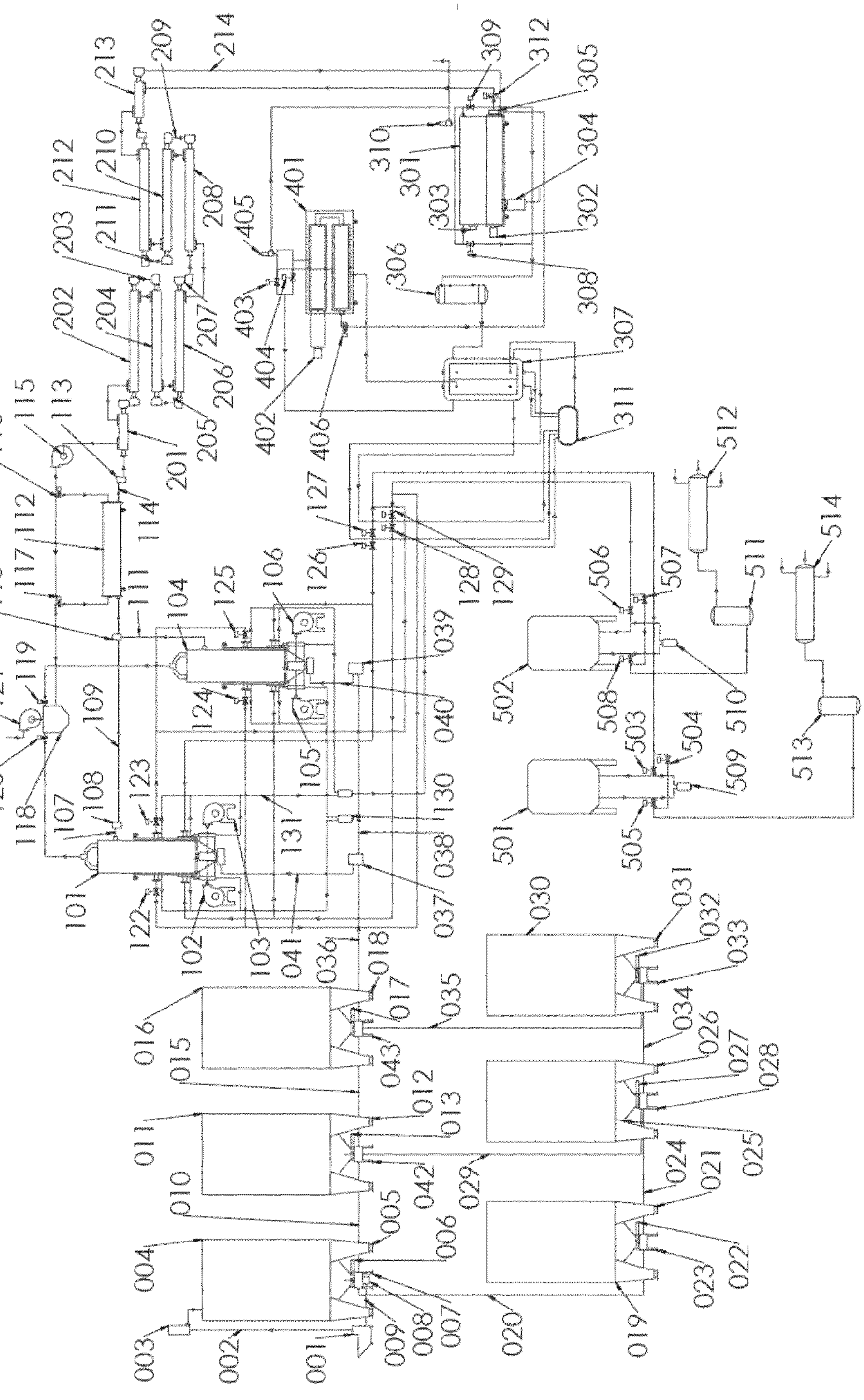

Figure 1

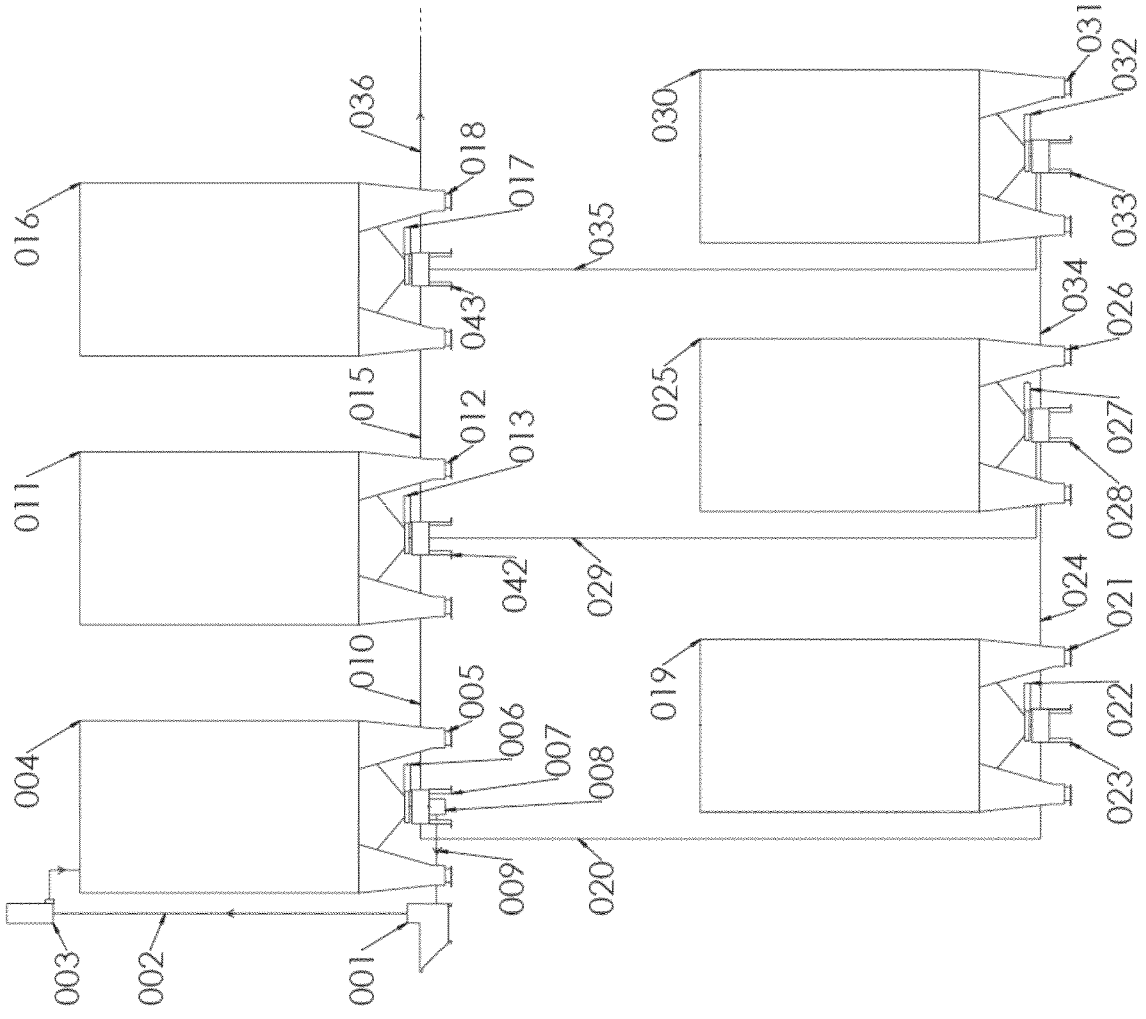
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Figure 1a

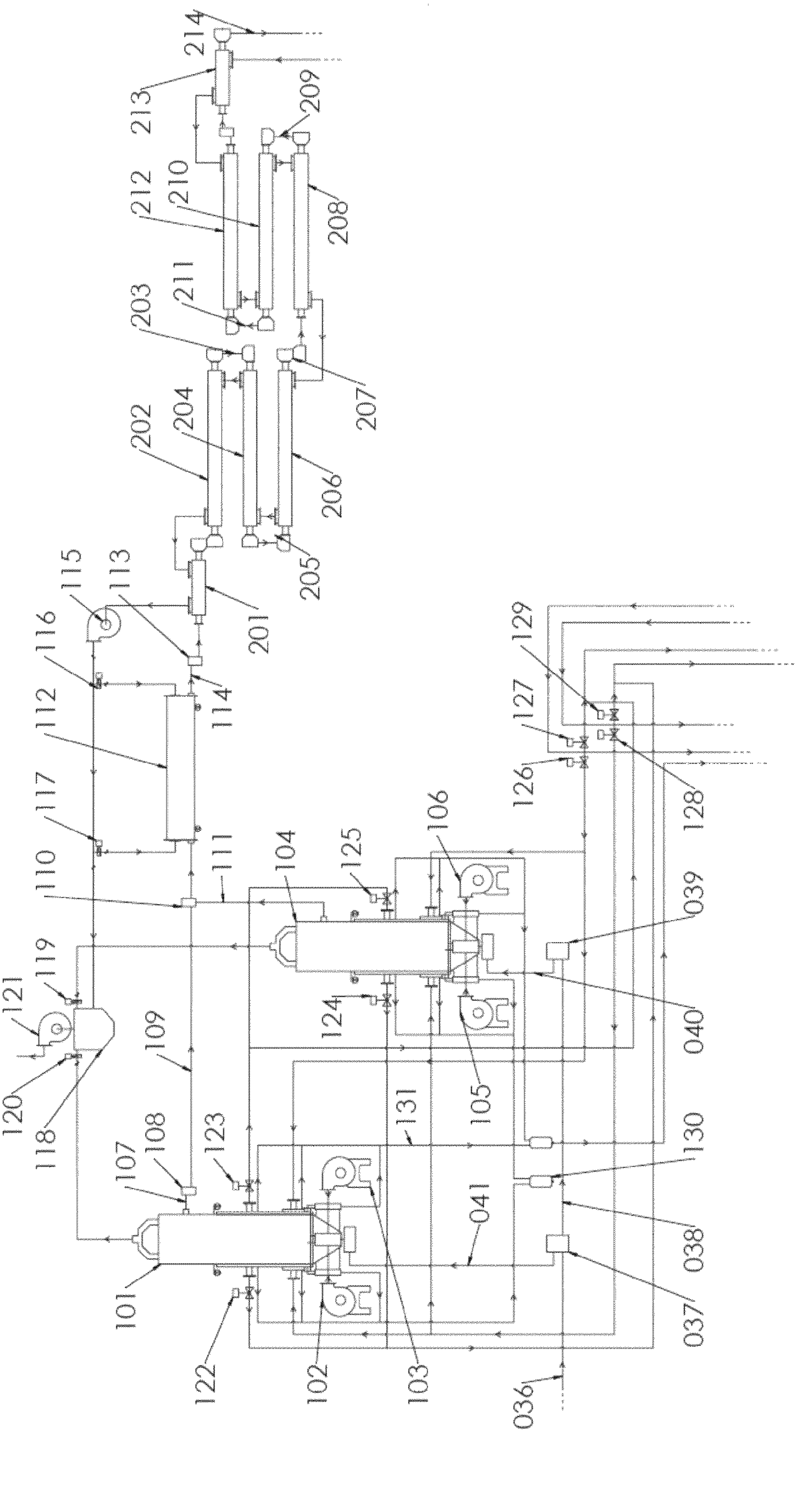
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Figure 1b

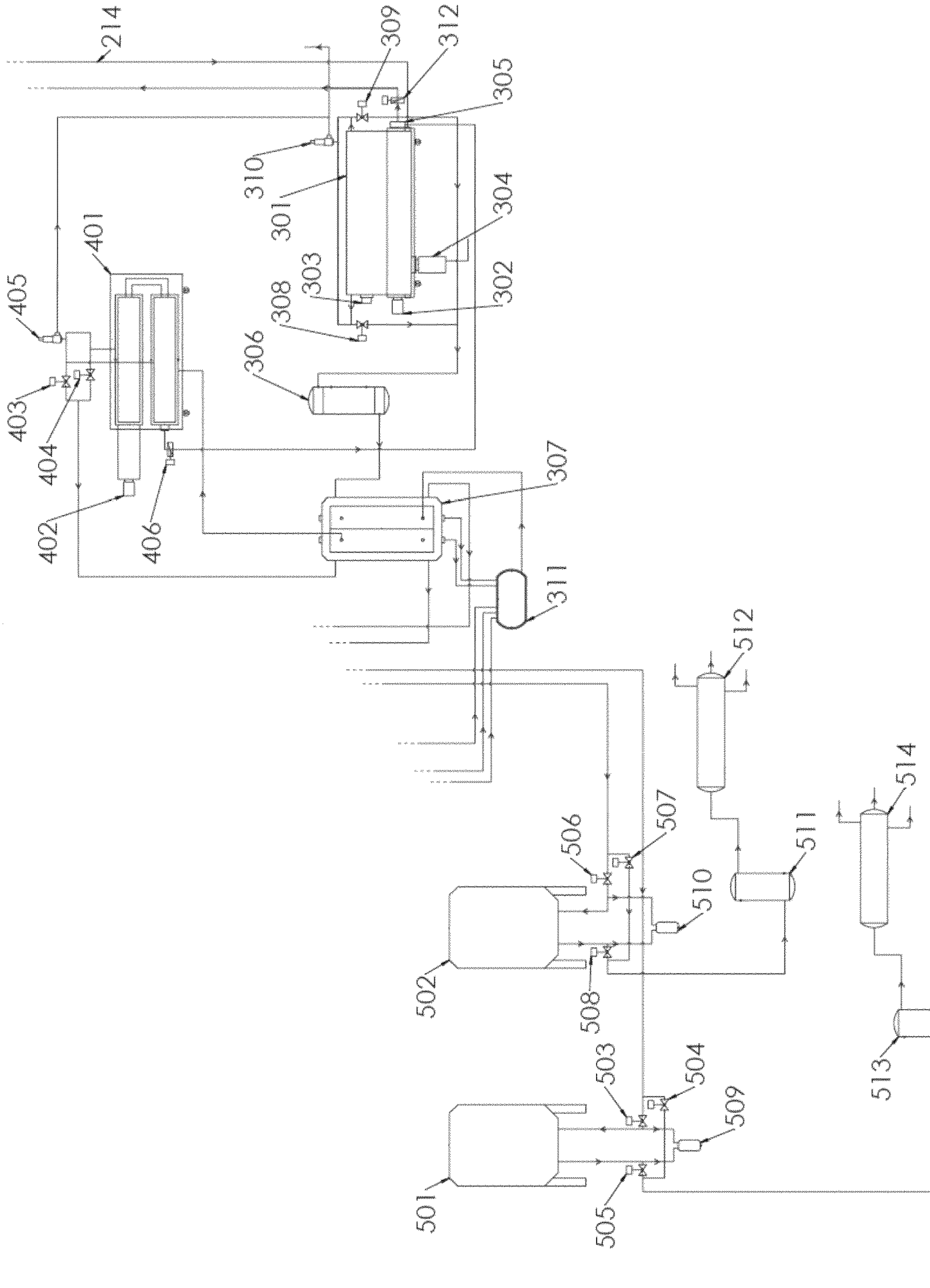
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Figure 1c

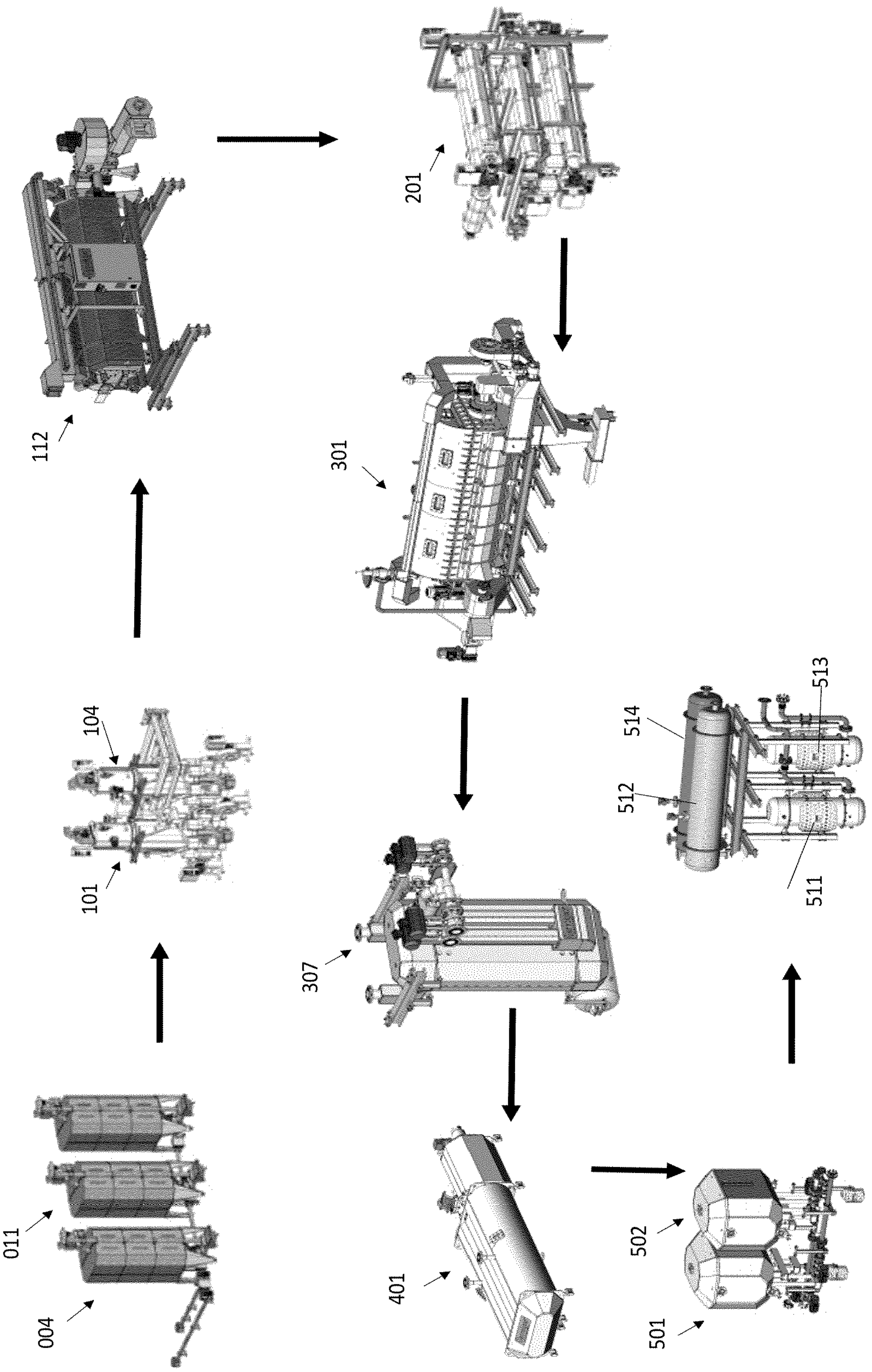

Figure 2

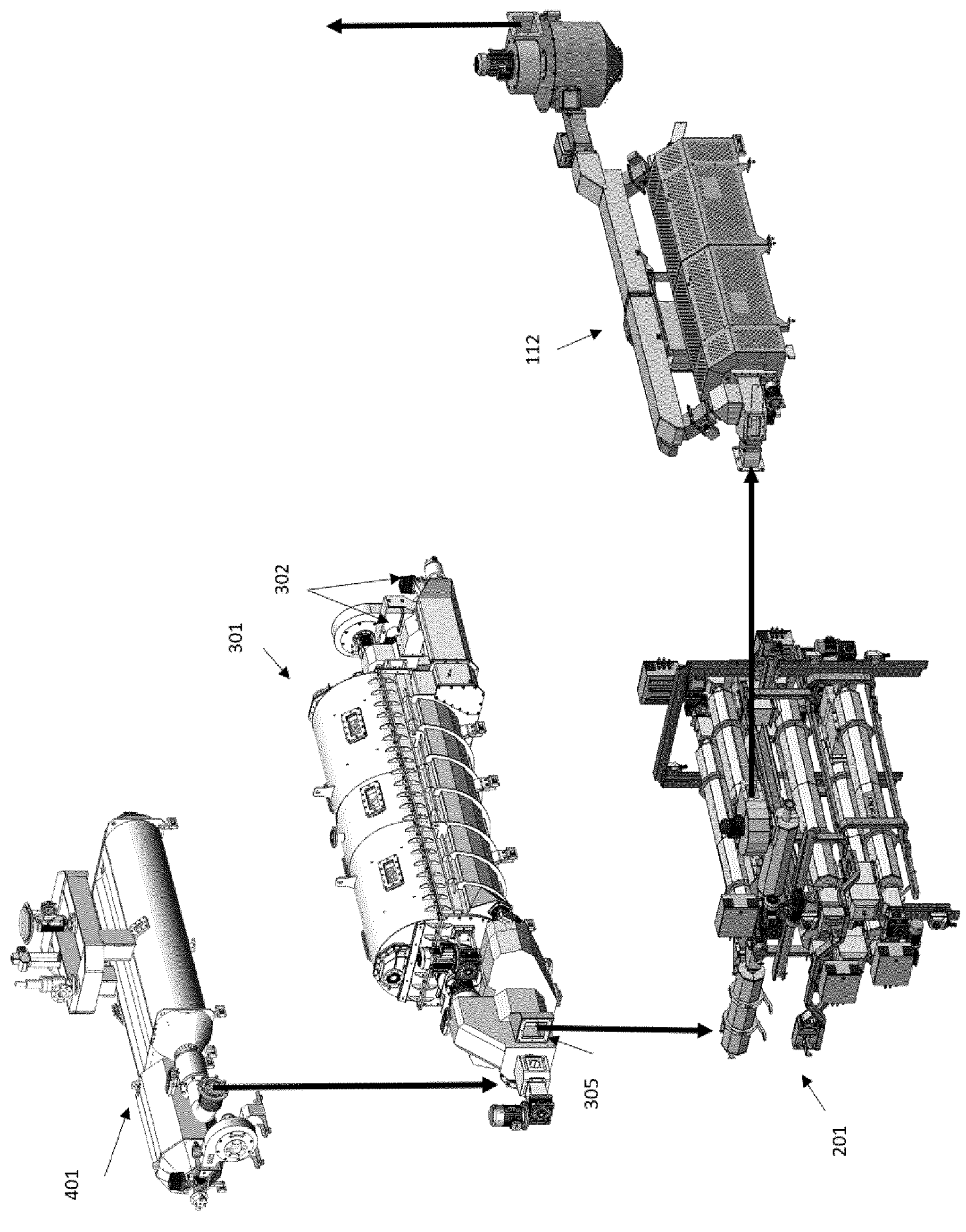

Figure 3

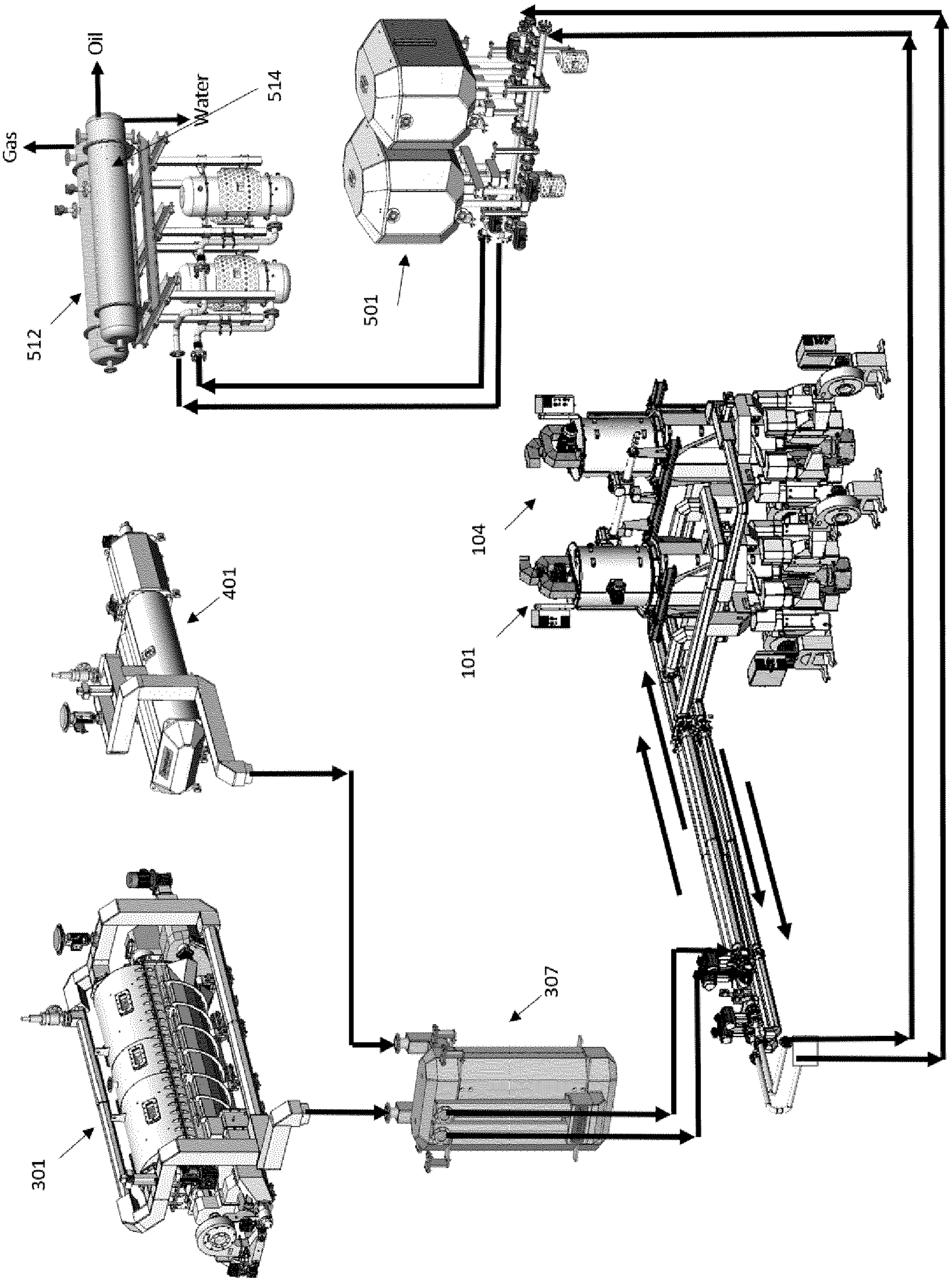

Figure 4

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 21 7838

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	EP 3 487 958 A1 (SYNTES ONE ENG GROUP APS [DK]) 29 May 2019 (2019-05-29) * paragraphs [0010], [0014] - [0025], [0033] - [0038] * * figures 1-4 * * claims 1-5 * -----	1-6, 11-13,18 7-10	INV. C10G1/10 C10B47/44 C10B53/07 C10B57/10
X A	US 2011/236516 A1 (YOSHIYAMA RYUJI [JP] ET AL) 29 September 2011 (2011-09-29) * paragraphs [0019] - [0031], [0036] - [0040], [0047] * * page 2 * -----	1 2-18	
X A	CN 111 662 732 A (SHANTOU GUYUAN NEW ENERGY CO LTD) 15 September 2020 (2020-09-15) * paragraphs [0060] - [0079] * * figure 2 * -----	13-18 1-12	
Y	US 6 178 899 B1 (KANEKO MASAKI [JP] ET AL) 30 January 2001 (2001-01-30) * column 9, line 60 - column 10, line 44 * * figure 2 * -----	7-9	TECHNICAL FIELDS SEARCHED (IPC)
Y	US 4 038 152 A (ATKINS LYLE D) 26 July 1977 (1977-07-26) * figure 3 * -----	10	C10B C10G C08J C10H
A	US 2018/010050 A1 (VAN DER REE TEUNIS [NL] ET AL) 11 January 2018 (2018-01-11) * the whole document * -----	1-18	

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	29 June 2022	Baumlin, Sébastien

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
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