



- (51) **International Patent Classification:**
B09B 3/00 (2006.01) *C01B 31/02* (2006.01)
F23G 5/027 (2006.01) *C10L 1/00* (2006.01)

(21) **International Application Number:**
PCT/US2012/040591

(22) **International Filing Date:**
1 June 2012 (01.06.2012)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
61/492,307 1 June 2011 (01.06.2011) US

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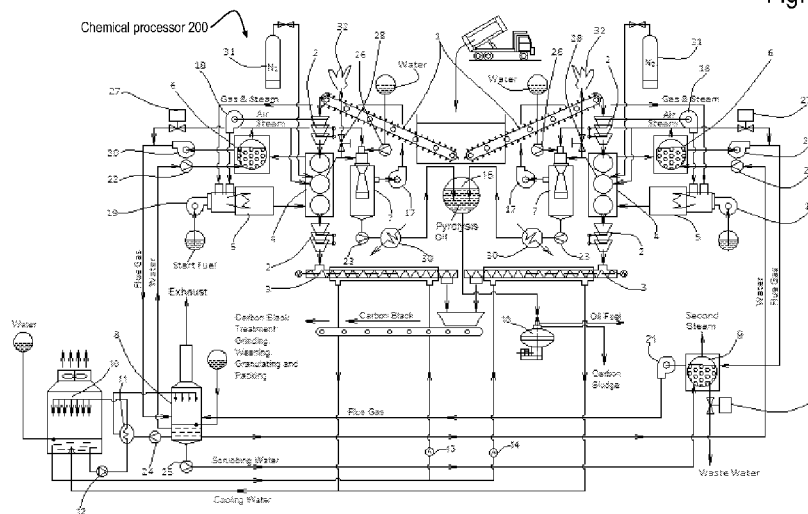
(81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) Title: PYROLYSIS-BASED APPARATUS AND METHODS

Fig. 1A



(57) Abstract: Apparatus and methods of operating hopper valves, reaction chambers, condensers, orifices, furnaces and chemical processors are disclosed and claimed. Several of the embodiments are specific to pyrolysis manufacturing processes. Some of the embodiments are applicable in situations where heat is used to decompose organic material, such as in the burning of wastes. The various embodiments contribute to improved quality for outputs such as carbon black and/or improved reliability by removing the potential for tar buildup and/or removing the possibility of dioxin contamination as a form of pollution.

Pyrolysis-Based Apparatus and Methods

Cross Reference to Related Patent Documents:

[001] This patent application claims priority to US Provisional Patent Application no. 61/492,307, filed June 1, 2011, entitled “APPARATUS AND METHOD FOR PYROLYSIS OF WASTE ORGANIC, PLASTIC, RUBBER AND USED TIRE MATERIALS AND RECOVERY OF VALUE INCREASED PYRO-OIL AND CARBON BLACK” which is incorporated herein by reference in its entirety.

Technical Field:

[002] This disclosure relates to apparatus and methods based upon continuous steam pyrolysis.

Background: Technical Problems

[003] Several terms that are well known in the prior art will be frequently used herein and are being derived from articles found in the Wikipedia:

[004] **Pyrolysis** is a thermochemical decomposition of organic material at elevated temperatures without the participation of oxygen. It involves the simultaneous change of chemical composition and physical phase, and is irreversible.

[005] The **Venturi** effect is the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe.

[006] The Venturi effect is a jet effect; as with a funnel the velocity of the fluid increases as the cross sectional area decreases, with the static pressure correspondingly decreasing. According to fluid dynamics, a fluid's velocity

must increase as it passes through a constriction to satisfy the principle of continuity, while its pressure must decrease to satisfy the principle of conservation of mechanical energy. Any gain in kinetic energy a fluid may accrue due to its increased velocity through a constriction is negated by a drop in pressure.

[007] A **Venturi tube** operates as follows: Fluid flows through a length of pipe of varying diameter. To avoid undue drag, a Venturi tube typically has an entry cone of 30 degrees and an exit cone of 5 degrees. To account for the assumption of an inviscid fluid a coefficient of discharge is often introduced, which generally has a value of 0.98.

[008] A **venturi scrubber** is designed to effectively use the energy from the inlet gas stream to atomize the liquid being used to scrub the gas stream. This type of technology is a part of the group of air pollution controls collectively referred to as wet scrubbers.

[009] It has been known for decades that the venturi configuration can be used to remove particles from gas streams, a process known as scrubbing.

[0010] A venturi scrubber consists of three sections: a converging section, a throat section, and a diverging section. The inlet gas stream enters the converging section and, as the area decreases, gas velocity increases (in accordance with the Bernoulli equation). Liquid is introduced either at the throat or at the entrance to the converging section.

[0011] The inlet gas, forced to move at extremely high velocities in the small throat section, shears the liquid from its walls, producing an enormous number of very tiny droplets.

[0012] Particle and gas removal occur in the throat section as the inlet gas stream mixes with the fog of tiny liquid droplets. The inlet stream then exits through the diverging section, where it is forced to slow down.

[0013] Venturis can be used to collect both particulate and gaseous pollutants, but they are more effective in removing particles than gaseous pollutants.

[0014] Current pyrolysis methods consist of two systems: pyrolysis in batch technologies and continuous pyrolysis technologies.

[0015] For the pyrolysis in batch technologies, feedstock materials of various types such as organic biomass, used plastics and used tires are placed in a pyrolysis furnace which is then heated to activate a pyrolysis reaction. Upon completion of the pyrolysis reaction, the furnace is cooled, depressurized and the pyro-products are removed. This prior art approach has the following disadvantages:

[0016] The pyrolysis furnace must be subjected to a repetitive heating and cooling cycle for each batch which limits the production capacity of the process and is an inefficient use of the energy required.

[0017] That because of the loading and unloading it is difficult to make effective use of the pyro-gases generated from the pyrolysis process.

[0018] During the unloading process a release of dust and pyro-gasses results which is a hazard to the environment.

[0019] Because of the above disadvantages the current preferred method of pyrolyzing feedstock is through the use of continuous pyrolysis methods. One of these methods is the continuous batch system which involves a series of reaction chambers connected together. The disadvantages of this system are:

[0020] Each reaction furnace has to be cooled and repeatedly heated.

[0021] Each reaction chamber must be unloaded and loaded repeatedly which incurs the disadvantages of a batch system referred to above.

[0022] The use of a series of reactors makes for a bulky plant configuration.

[0023] The individual operation of each furnace complicates the pyrolysis operation.

[0024] The second method is a continuous pyrolysis system which does not incorporate the plurality of parallel pyrolysis furnaces. This system is a dry pyrolysis method which uses a dry inert gas to carry the resultant pyro-gas out. The disadvantages of this system are:

[0025] There is a danger of explosion in the furnace as a significant amount of combustible gases are generated during the high temperature process.

[0026] Sulfurous components in the feedstock materials will be released, leaving a high sulfur content in the pyrolysis by products produced, thereby lowering the quality and merchantability of the resultant by products.

[0027] There is not readily-available a cost effective inert gas in the pyrolysis industry having the capability of carrying the pyro-gas out or a method of self-generating an inert gas having the capabilities required and it must be either specially produced or

the supply of an inert gas has to be outsourced, thereby significantly increasing the operating costs of the system.

[0028] The current steam pyrolysis systems provide a system to address the disadvantages of the previous pyrolysis methods and allows for continuous pyrolysis without the requirement of multiple pyrolysis furnaces. The advantages of the steam pyrolysis system are:

[0029] Less Environmental impact as there is a minimal amount of Non-combustible waste produced.

[0030] No burning and no landfill requirements as there is a more complete cracking of feedstock.

[0031] Less tar produced than competitive batch systems.

[0032] More efficient re-use of gases produced from the steam pyrolysis system by using these gases for fuel for heating the furnace.

[0033] Minimal vacuum required ensuring safer operation.

[0034] Ability of Steam system pyrolysis to process variable feedstocks.

[0035] Ability of Steam system pyrolysis to operate on a Continuous basis.

[0036] Summarizing the problems found in prior art pyrolysis systems and methods:

[0037] Experience has shown that there is a buildup of soot in the water cooled condensers resulting in a tar buildup in the condensers and piping system. This occurs because of the formation of tar and contamination upon the cooling surface of such condensers, including the steam condensate. This resulting pyrolysis fuel representing a mixture of water with light and heavy mazut is not suitable for burning in a standard light diesel fuel burner.

[0038] Experience has shown that the steam condensate is impure containing water soluble benzenes, benzynes and other light rubber factions which condense with the steam including minor hydro-suspensions of insoluble fractions. In the boiler and in the condensers this organic matter is condensed and upon repetition of the process increases the yield to 9%-10% of the material feedstock. The operation of steam boilers currently available in industry are unable to handle a condensate having this quantity of organic impurities.

[0039] The quality of carbon black or activated carbon under the current steam pyrolysis system may achieve only 95% purity which makes the carbon black or activated carbon produced less marketable.

[0040] Experience has shown that the flash point of fuel oil produced when using used tires as feedstock material is less than 40°C. This results from the use of water cooled condensers by the existing steam pyrolysis systems and their lower condensing temperature which produces a less marketable fuel oil.

[0041] The current system pyrolysis systems incorporate an auger or conveyor system which do not provide for a thorough mixing of the feedstock with the superheated steam, thereby lessening decomposition of the feedstock and the purity of the by-products produced.

[0042] The current steam pyrolysis systems, which through experience have shown, are capable of producing a carbon black having a relatively high purity, however as they incorporate only one or two reactors in the reaction chamber, the length of time for processing the feedstock material in these systems is not sufficient for decomposing all the volatiles from the material to be pyrolyzed or the carbon by-products produced making it difficult, if not impossible, to produce a purity of carbon black or activated carbon approaching 99%.

[0043] The current steam pyrolysis systems do not incorporate a fire suppression system which eliminates the danger of fire and explosion in the event of a shutdown of the system caused from a power failure.

[0044] The current steam pyrolysis systems do not incorporate an emergency system to safely remove pyro-gas from the reaction chamber in the event of a shutdown of the pyrolysis system due to a power failure.

[0045] The current steam pyrolysis systems use a dual blade gate valve system at the entry to the reactor and a dual blade gate valve at the discharge exit in the reactor to reduce access of air into the reactor which experience has shown that such gate valves start to leak air into the reactor during continuous use due to a build of particulate matter on the blade gate valves creating an improper seal.

[0046] The current steam pyrolysis systems do not generate a sufficient amount of super heated steam thereby causing an insufficient pressure in the reactors to ensure that no air enters thereby increasing the risk of explosion of the pyrogas produced therein and reducing the effectiveness of the pyrolysis system as a whole.

Summary of the Invention:

[0047] Apparatus and methods of operating hopper valves, reaction chambers, condensers, orifices, furnaces and chemical processors are disclosed and claimed. Several of the embodiments are specific to pyrolysis manufacturing processes. Some of the embodiments are applicable in situations where heat is used to decompose organic material, such as in the burning of wastes. The various embodiments contribute to improved quality for outputs such as carbon black, and/or improve reliability by removing the potential for tar buildup, and/or removing the possibility of dioxin contamination as a form of pollution.

[0048] The chemical processor may be adapted to generate carbon black from used tires, plastics, human or animal wastes, silage and/or other carbon rich materials.

[0049] As used herein, a low complexity hydrocarbon gas may include benzene, benzyne and/or other molecules with less than 30 atoms that are mostly hydrogen and carbon.

[0050] The low complexity gas may be gaseous at room temperature, or more importantly, at the boiling point of water, which at sea level is about 100 degrees Centigrade (C).

[0051] These low complexity hydrocarbon gases are responsible for reacting with air to form various dioxin compounds. These dioxin compounds are dangerous pollutants resulting from many chemical processes including the burning of wastes.

[0052] Various embodiments disclosed herein can be operated to remove the possibility of generating these pollutants, thereby positively affecting the environment and many people.

[0053] The furnace may include the orifice adapted to ignite the furnace using a high BTU fuel. As the chemical processor stabilizes into normal operation, a return gas with a low BTU may be turbulently mixed with air by the orifice to create a high BTU fuel in the furnace, without requiring an external source.

[0054] The condenser may be adapted to receive a pyrolysis off-gas and adapted to support at least one of

[0055] maintaining an internal temperature of the condenser at or above 100 degrees Centigrade (C) to keep any low complexity hydrocarbon gas in the pyrolysis off-gas from condensing to contaminate a fuel oil created from the pyrolysis off-gas and/or

[0056] using water droplets within the condenser to mix with particulates in the pyrolysis off-gas to condense the particulates out of a return gas and into the fuel oil.

[0057] Some embodiments may also address the technical problem of maintaining an air-tight environment in the reactors 82, since the removal of pyrolysis gases from the reactors are carried out under rarefaction and create a vacuum. A number of devices may be used to prevent the leakage of air into the reactors 82. Devices such as sluices, valves or seals may isolate the reactors from outside air, but have proven to have some deficiencies. These deficiencies may lead to ignition and explosive inflammation of pyrolysis fragments and products, causing the whole chemical processor to dangerously fail.

[0058] Some embodiments may also address the other problems of the existing steam pyrolysis systems mentioned by providing at least one, and in some embodiments, all of the following.

[0059] The reaction chamber housing 77 may be formed to reduce the open space inside the reaction chamber housing 4 thereby maximizing the heat flow velocity and the efficiency of convective heating in the reaction chamber 4.

[0060] The exterior walls 77 of the reaction chamber 4 may be made of a porous castable refractory material consisting of a vermiculite-fireclay-alkaline content which when mixed with water enables the forming of the reaction chamber housing 77 so as to reduce the open areas in the reaction chamber 4.

[0061] The interior of the reaction chamber housing 77 may include an inner lining of fireclay concrete and the exterior of the reaction chamber housing 77 may be encompassed in a steel case.

[0062] The method, without the use of a water cooled surface, may separate the steam from the fuel oil and may not condense the steam during condensation of the fuel oil. This eliminates a tar build up in the condensers and piping system, as well as the problem of steam condensate contamination by the soluble fractions of the condensed fuel oil.

[0063] Condensing steam outside of the oil condensers thereby creating steam condensate free of organic particulates eliminates the problem of a repetitive build up of organic soot, thereby permitting reuse of the condensate in the boiler 6.

[0064] Extending the time for removal of volatiles from the residual carbon black produced from the pyrolyzing of the feedstock materials through the operation of a second and third reactor in the reactor chamber increases the purity of the carbon black up to 99%.

[0065] Operating a condenser whereby the fuel oil produced from the pyrolyzing of used tire feedstock material has a flash point of not less than 75. This enhances the marketability of the fuel oil and provides a quantity of residual off-gas sufficient for heating the reaction chamber by burning of the off-gas without using the fuel oil produced.

[0066] Incorporating an Alfa Laval separator 16 for cleaning the condensed fuel oil separates the combustible light fuel from the heavy mazut, oil fractions and pyrolitic carbon. After separation there remains up to 2% to 3% of mazut-carbon sludge. The heavy oil fractions remain and form a mazut-carbon-slime, which can be subsequently added to the feedstock material and reprocessed through the system.

[0067] Operating an orifice to provide a vortex pre-mixing chamber for the off-gas burning furnace with a standard oil burner for starting the fuel gas during ignition, then turning off the starting fuel.

[0068] Ensuring that at least 30% of superheated steam by weight in relation to the weight of the feedstock material is injected into the pyrolysis reactors, reduces the possibility of air entering into the reactors and creates a more thorough heat penetration into the feedstock material during the pyrolysis process.

[0069] Operating the hopper valves by using hinged dual flap air lock gates instead of dual blade gates eliminates particulate build up of material to be pyrolyzed occurring in the sliding blade gates.

[0070] The outside air is extracted from the first hopper bin 2 for burning the off-gas prior to entry of the feedstock material to be pyrolyzed into the first reactor 82. This

eliminates the possibility of air entering into the reactors and assists in eliminating the feedstock odors. It also eliminates the possibility of an explosion if there is any defect of the dual flap gates during the pyrolysis operations.

[0071] An emergency nitrogen fire suppression system may be connected to the reactors to remove the possibility of a fire, if the steam injection system has a situation that may cause a fire. A temperature control device may preferably discharge nitrogen into the reactors if the temperature increases above 700 degrees C. The emergency system may also safely disperse explosive pyrolysis off-gases contained in the reactors in the event of an electrical power shut down.

[0072] The piping system may be cleaned of a buildup of soot through the disclosed access to the piping, thereby preventing operational shutdown of the pyrolysis system from soot buildup.

[0073] The auger system includes one or more blending zones, the total length of the blending zones ranging from 5% to 35% of the total length of the proceeding zones.

Brief Description of Figures:

[0074] Figure 1A shows a schematic diagram of an example process flow and may be seen as a simplified block diagram of an example embodiment of a chemical processor including two hopper valves, both coupled to a reaction chamber to control input of raw material as feedstock and output of carbon black without introducing air into the reactor chamber, a furnace, and a condenser.

[0075] Figure 1B is a schematic diagram of the control and monitoring process of Figure 1A.

[0076] Figure 2 shows some details of the reaction chamber of Figure 1A receiving the feedstock mixed with pressurized steam as the input lacking air into a first reactor, heats the input through two or more additional reactors, generating a pyrolysis off-gas in the process, as well as carbon black as the output.

[0077] Figure 3A and Figure 3B show the operation of the first and second dump gates of one of the hopper valves of Figure 1A and Figure 2.

[0078] Figure 4A to Figure 4G show some details of various embodiments of the reaction chamber of Figure 1 and Figure 2, in particular:

[0079] Figure 4A shows cross sectional drawings representing side and overhead views of a preferred embodiment of the containment housing for the reaction chamber.

[0080] Figure 4B shows isometric drawings representing an alternative embodiment of the containment housing for the reaction chamber which encases the furnace and steam boiler.

[0081] Figure 4C shows a cross sectional and side view of the reactor chamber and the reactors located therein.

[0082] Figure 4D shows the decomposition process and flow gases and steam through the reactors.

[0083] Figure 4E shows a cross sectional view of an embodiment of a pyrolysis reactor chamber for implementing the blending method of this disclosure.

[0084] Figure 4F and Figure 4G show some details of an augur system that may be used in one or more of the reactors. Note that the reactors may or may not all use the same kind of augurs.

[0085] Figure 5A and Figure 5B show some details of the condenser of Figure 1A.

[0086] The pyrolysis off-gas, steam and water droplets are input to the condenser that maintains an internal temperature of about or above 100 degrees C.

[0087] The condenser uses the water droplets to capture particulates out of the steam that would otherwise contribute to tar build up from the contaminated steam passing through the piping of the chemical processor.

[0088] The condenser is also adapted to avoid condensing low complexity hydrocarbon gases as it condenses the pyrolysis off-gas to generate fuel oil, by maintaining an internal temperature of about or above 100 degrees C.

[0089] The low complexity hydrocarbon gases and some of the steam are output from the condenser as a return gas to the furnace.

[0090] Figure 6 shows some details of the furnace of Figure 1A including the orifice adapted to input the pyrolysis off-gas, steam and water droplets to internally create a high BTU fuel burned during normal operations as well as an ignited fuel oil to initiate burning in the furnace.

[0091] Figure 7A to Figure 7C show some details of an example orifice of Figure 6.

[0092] Figure 8 shows a cross section view of an embodiment of a piping section implementing the method of disassembling and reassembling of the piping system of this disclosure so as to enable cleaning of the piping system.

Detailed Description of Figures:

[0093] This disclosure relates to apparatus and methods based upon continuous steam pyrolysis. The detailed description will start by summarizing a typical embodiment of the apparatus and manufacturing process in terms of the Figures and reference numbers. Once the summary has been discussed, a more detailed discussion of the Figures will follow.

[0094] Figure 1A shows a schematic diagram of an example process flow and may be seen as a simplified block diagram of an example embodiment of a chemical processor including two hopper valves, both coupled to a reaction chamber to control input of raw material as feedstock and output of carbon black without introducing air into the reactor chamber, a furnace, and a condenser.

[0095] Figure 1A shows a chemical processor the operates by feeding a material to be pyrolyzed into a reaction chamber 4 heated by a furnace 5 producing heated air having a temperature of between 1000°C – 1100°C which upon entering the reaction chamber 4 is reduced to between 800°C – 850°C and upon exiting is further reduced to a temperature between 600°C – 650°C.

[0096] Figure 1B is a schematic diagram of the control and monitoring process of Figure 1A.

[0097] Figure 2 shows some details of the reaction chamber of Figure 1A receiving the feedstock mixed with pressurized steam as the input lacking air into a first reactor, heats the input through two or more additional reactors, generating a pyrolysis off-gas in the process, as well as carbon black as the output.

[0098] Figure 3A and Figure 3B show the operation of the first and second dump gates of one of the hopper valves of Figure 1A and Figure 2.

[0099] Figure 4A to Figure 4G show some details of various embodiments of the reaction chamber of Figure 1 and Figure 2, in particular:

[00100] Figure 4A shows cross sectional drawings representing side and overhead views of a preferred embodiment of the containment housing for the reaction chamber.

[00101] Figure 4B shows isometric drawings representing an alternative embodiment of the containment housing for the reaction chamber which encases the furnace and steam boiler.

[00102] Figure 4C shows a cross sectional and side view of the reactor chamber and the reactors located therein.

[00103] Figure 4D shows the decomposition process and flow gases and steam through the reactors.

[00104] Figure 4E shows a cross sectional view of an embodiment of a pyrolysis reactor chamber for implementing the blending method of this disclosure.

[00105] Figure 4F and Figure 4G show some details of an auger system that may be used in one or more of the reactors. Note that the reactors may or may not all use the same kind of augers.

[00106] Figure 5A and Figure 5B show some details of the condenser of Figure 1A.

[00107] The pyrolysis off-gas, steam and water droplets are input to the condenser that maintains an internal temperature of about or above 100 degrees C.

[00108] The condenser uses the water droplets to capture particulates out of the steam that would otherwise contribute to tar build up from the contaminated steam passing through the piping of the chemical processor.

[00109] The condenser is also adapted to avoid condensing low complexity hydrocarbon gases as it condenses the pyrolysis off-gas to generate fuel oil, by maintaining an internal temperature of about or above 100 degrees C.

[00110] The low complexity hydrocarbon gases and some of the steam are output from the condenser as a return gas to the furnace.

[00111] Figure 6 shows some details of the furnace of Figure 1A including the orifice adapted to input the pyrolysis off-gas, steam and water droplets to internally create a high BTU fuel burned during normal operations as well as an ignited fuel oil to initiate burning in the furnace.

[00112] Figure 7A to Figure 7C show some details of an example orifice of Figure 6.

[00113] Figure 1A shows a chemical processor 200 that operates by feeding a raw material to be pyrolyzed into a reaction chamber 4 heated 222 by a furnace 5 producing heated air having a temperature of between 1000°C – 1100°C which upon entering the reaction chamber 4 is reduced to between 800°C – 850°C and upon exiting is further reduced to a temperature between 600°C – 650°C.

[00114] Figure 1B is a schematic diagram of the control and monitoring process of the chemical processor 200 of Figure 1A.

[00115] Figure 2 shows some details of the reaction chamber 4 of Figure 1A receiving the raw material as feedstock input 210 mixed with pressurized steam 220 in the first hopper valve 2 as the input lacking air sent into a first reactor 82, heat 222 is applied, that may preferably be in the form of heated air to the input through two or more additional reactors 82, generating a pyrolysis off-gas 230 in the process, as well as carbon black output 212 which leaves the reaction chamber 4 through the second hopper valve 2.

[00116] Figure 3A and Figure 3B show the operation of a first dump gate 110 and a second dump gate 112 of one of the hopper valves 2 of Figure 1A and Figure 2.

[00117] Figure 3A shows the first dump gate 110 open allowing gravity and/or a pressure differential to urge material in the top hopper into the middle hopper. The second dump gate 112 is shown closed, which may be preferred to reduce the possibility of oxygen entering into the middle hopper.

[00118] Figure 3B shows the first dump gate 110 closed and the second dump gate 112 open allowing gravity and/or a pressure differential to urge material in the middle hopper into the bottom hopper, which may be adapted to

[00119] feed the feedstock input 210 and steam 220 mixture into the reaction chamber 4 for the first hopper valve 2 of Figure 2 or

[00120] feed the carbon black output 212 from the Nth reactor 82 of Figure 2.

[00121] Figure 4A to Figure 4G show some details of various embodiments of the reaction chamber of Figure 1 and Figure 2, in particular:

[00122] Figure 4A shows cross sectional drawings representing side and overhead views of a preferred embodiment of the containment housing for the reaction chamber 4.

[00123] Figure 4B shows isometric drawings representing an alternative embodiment of the containment housing for the reaction chamber 4 which encases the furnace and steam boiler.

[00124] Figure 4C shows a cross sectional and side view of the reactor chamber and the reactors located therein.

[00125] Figure 4D shows the decomposition process and flow gases and steam through the reactors.

[00126] Figure 4E shows a cross sectional view of an embodiment of a pyrolysis reactor chamber for implementing the blending method of this disclosure.

[00127] Figure 4F and Figure 4G show some details of a screw augur system that may be used in one or more of the reactors. Note that the reactors may or may not all use the same kind of augurs.

[00128] Figure 5A and Figure 5B show some details of the condenser of Figure 1A.

[00129] The pyrolysis off-gas, steam and water droplets are input to the condenser that maintains an internal temperature of about or above 100 degrees C.

[00130] The condenser uses the water droplets to capture particulates out of the steam that would otherwise contribute to tar build up from the contaminated steam passing through the piping of the chemical processor.

[00131] The condenser is also adapted to avoid condensing low complexity hydrocarbon gases as it condenses the pyrolysis off-gas to generate fuel oil, by maintaining an internal temperature of about or above 100 degrees C.

[00132] The low complexity hydrocarbon gases and some of the steam are output from the condenser as a return gas to the furnace.

[00133] Figure 6 shows some details of the furnace of Figure 1A including the orifice adapted to input the pyrolysis off-gas, steam and water droplets to internally create a high BTU fuel burned during normal operations as well as an ignited fuel oil to initiate burning in the furnace.

[00134] Figure 7A to Figure 7C show some details of an example orifice of Figure 6.

[00135] Now to discuss the Figures in greater detail:

[00136] Figure 4A to Figure 4E show the reaction chamber 4 containing three reactors 82 and carrying out a pyrolysis reaction in the presence of a superheated steam flow. The material to

be pyrolyzed passes through one or more proceeding zones 94 and one or more blending zones 95 in each reactor 93, the material to be pyrolyzed passing from the first reactor 93 to the second reactor 93 and then the third or more reactors. The total length of one or more blending zones in each reactor may range from 5% to 35%. The reactors 93 may utilize high-temp steam and a re-circulating heat source to crack dioxin and organic substances contained in the feedstock material. The off gas mixture produced in the reactors 93 is discharged into an off gas mixture treatment system including a condenser 7 first shown in Figure 1A for separation at a temperature between 100°C – 110°C. The used steam and off gas after separation from the fuel oil are both re-introduced into a furnace 5 for producing heat.

[00137] This disclosure includes a continuous pyrolysis method for pyrolyzing organic materials including used tires comprising the following:

[00138] A charge opening in the first reactor (input of Figure 4D) and a discharge opening (output of Figure 5) in the third or last of the three or more reactors 82 installed in the reaction chamber 4. Each of the transporting structures 92 in each reactor 82 has a central axis and comprises a plurality of spiral structures 94 starting from the opening charge and continuing through in a forward direction from the entry into the first reactor and into a second reactor and moving forward from the opening charge of the second reactor and continuing into a third or additional reactor. The spiral structures start at the opening charge and continue forward to the discharge of the third reactor. Each reactor 82 containing a plurality of paddle structures 95 disposed along the axis direction. Each of the transporting structures 92 contained in each reactor 82 consists of paddle segments 95 of substantially the same in width and length and each of spiral segments 94 is substantially identical in width and length. Preferably the total length of paddle segments ranges from 5% to 30% of the length of the transporting structure 96 and a loading limit of feedstock to not more than 50% of the volume of the first reactor (pyrolysis material of Figure 4D), the amount to be determined having reference to the diameter and length of the first reactor 96, and is readily determinable by those familiar with the art. In this preferred embodiment of the invention the augers are rotated by a gear motor 87 having a continuous variable transmission with a speed sensors 86. The Gear-motor is mounted on the second screw auger from which chain gears 84 rotate the other 2 screw augers. Because the transporting structure 92 of this disclosure comprises paddle segments 95, the material to be pyrolyzed (Pyrolysis Material of Figure 4D) is stirred and blended thereby permitting a thorough penetration of the feedstock material

(Pyrolysis Material of Figure 4D) by the superheated steam 85 which affects a more complete and homogeneous pyrolysis of the feedstock material.

[00139] The screw augers 91 located in the reactors 82 may be driven by any appropriate driving means 87, a preferred embodiment in this invention being a reduction electric motor, while the rotational speed of the axial transporting structures 92 can be adjusted depending on the size, composition and time required to optimize the decomposition of the feedstock material into the desired specification of the by-products. In the preferred embodiment of this invention, the reactors 82, the transporting structures 92 and blending blades 95 are made of stainless steel SS 321.

[00140] The injected superheated steam 88 unclogs and displaces the volatiles 89 contained in the feedstock material (Pyrolysis Material of Figure 4D) and carbon black produced from the pyrolysis process and creates a thorough steam diffusion of the volatiles 89 in the feedstock material (Pyrolysis Material of Figure 4D) and the residual carbon black in the reactors 82. The presence of superheated steam 88 in this disclosure reduces the pyrolysis temperature required below that of the current pyrolysis systems which do not use steam thereby increasing the energy efficiency of the invention. Further the injected steam assists in reducing the vacuum created by pyrolysis systems which do not use steam, thereby assisting in eliminating the danger of air entering into the reactors 82 and the possibility of a resulting explosion of the pyro-gas produced. To further assist in removing this danger, the invention incorporates a steam generation system 6 whereby the injected steam represents not more than 30% -35% by weight in relation to the weight of the feedstock material (Pyrolysis Material of Figure 4D).

[00141] This disclosure includes a method whereby superheated steam is injected into an opening (a steam inlet) in the third reactor 82 at the temperature of 400 degrees C- 450 degrees C and then continuing through that reactor into the second and then the first reactors. The superheated steam is discharged, either through a steam and pyrolysis gas outlet opening in either the first or second reactor, together with the off-gas created from the pyrolysis process at the off-gas and steam discharge opening (Pyrogas+Steam in Figures 4 and 5).

[00142] This disclosure includes a continuous pyrolysis apparatus containing two double flap gate air lock valves 2 and a dual hopper valve for loading the first reactor 82 prior to the entry of the feedstock material into the first reactor 82 and double gate flap air lock valves 2 at the

exit of the pyrolyzed material (Pyrolysis Material of Figure 4D) from the third or last reactor together with a dual hopper valve 2 for the unloading of the third or last reactor. The double flap gate air lock valves 2 prevent air from entering the reactors 82 when loading the materials to be pyrolyzed and when unloading the carbon black at the discharge exit of the third or a last reactor 82.

[00143] This disclosure provides a vacuum fan 18 in the open top-hopper loading valve to continually extract any present outside air in the top-hopper which is sent to the post-combustion furnace 5 for burning. This method assists in eliminating unpleasant odors emanating from the reactors 82 while at the same time assisting in restricting air from entering the reactors 82. This measure assists in maintaining the reactor integrity and fan dilution.

[00144] This disclosure includes a heating furnace 5 equipped with a standard automatic burner 19 for liquid fuel with a three stage regime of regulation which allows the production of heat to the reaction chamber 4 when starting the pyrolysis process and as a source of ignition to support the after burning residual gaseous by product produced from pyrolysis. A preferred embodiment would have a flow rate of 75-80 litres of fuel per hour and a flow rate of 15-20 litres per hour relative to the 1,000 kgs/hr of tire pyrolysis rate. Ignition is produced in a small chamber before the main chamber, where in a narrow annulus around the pipe burner, a mixing of gaseous by-products mix with air achieving a combustion and heat residual having the intensity of fuel oil. Channel size and speed of the vapor-gas mixture in it are determined by those familiar with the art.

[00145] The temperature in the furnace 5 is within the range of 900 degrees C – 1100 degrees C and is controlled by two regulators 61 and 62 one operating at 900 degrees C – 1000 degrees C and the other subsequently at 1000 degrees C – 1100 degrees C, both operating continuously and in cohesion with each other. The first being an automatic regulator within the burner 61 which controls the amount of diesel fuel consumed when starting the pyrolysis process and secondly by an automatic control for firing 62 through a control number supplied to the system using a pair of HISS bypass valves controlling the supply of gaseous by-products from the condenser 7. When in a continuous operation mode, the more of the gaseous material that passes, the less steam in the system and the higher the temperature in the furnace and vice versa. Fan 18 supplies air to the combustion chamber. Fan 17 supplies residual gaseous products including water vapor that come from the condenser with a

temperature slightly above 100 degrees C. The volume of these is controlled by a regulator 62.

[00146] The invention has 3 tubular reaction chambers 83. In the preferred embodiment of the invention the feedstock material is loaded into the first reactor 82 (being the upper reactor) having the surface wall temperature between 300 degrees C – 400 degrees C. The feedstock material is moved along the length of the first reactor to the second reactor 82 which has a temperature of between 400 degrees C – 500 degrees C and to the third reactor 82 which is located below and having a temperature of between 500 degrees C – 600 degrees C. In the preferred embodiment of the invention, the total time spent by the feedstock material in the reactor chambers 83 prior to being discharged would be approximately 17 minutes, during which time the temperature of the feedstock materials will reach between 400 degrees C – 450 degrees C. In the preferred embodiment the first and second reactors are made with stainless steel SS321 and the third reactor is made with stainless steel SS310. This disclosure includes that the time for processing the feedstock material may be varied by those familiar with the art by varying the speed of the screw augers so as to produce the desired grade of carbon black or activated carbon.

[00147] This disclosure includes a screw conveyor with an external cooling jacket 3 which cools the temperature of residue carbon at the reactor outlet from approximately 400 degrees C to approximately 50 degrees C. This cooling apparatus is cooled by water from a cooling tower 10 which circulates in an outer jacket in the opposite direction of the screw auger.

[00148] This disclosure includes for a steam generator 6 which produces a sufficient supply of steam for the efficient thermal decomposition of the feedstock material in the reactors 82 and stable condensation of pyrolysis fuel in the condenser 7. In this preferred embodiment steam is generated at temperatures up to 150 degrees C and at a pressure of 5 bars from water diverted from the scrubber 8 which condenses the exhaust steam contained in flue gas after the off-gas burning in the furnace which is firstly generated from the reactors 82 together with the residual steam from the oil condenser 7 thereby collecting all water in the steam and reusing it to produce steam again. The volume of steam and the pressure to be generated required is commonly known to those familiar in the art.

[00149] This disclosure includes a fan-exhauster 20 which draws furnace gases from the reaction chamber 4 and which are cooled in the steam generator 6 to 200 degrees C -250

degrees C, the size of the steam generator is determined by special calculations performed by those familiar in the art and known to the industry. In this preferred embodiment a level sensor 57 permits adjustment of the amount of water entering the steam generator so as to maintain the required amount of water in the installation. From the boiler 6, steam is sent to the tubular super heater 85 contained in the reaction chamber 4 to heat the steam to 400 degrees C-450 degrees C which is then fed directly into the reactors 82 for contact with the feedstock material to be pyrolyzed in a volume which is determined and controlled by the temperature sensor 35. Together with pyrolysis fuel gas produced the superheated steam then goes to the condenser 7 where the fuel gas is sent for evaporative spray cooling by water and combined as a residue with the steam for burning in the furnace 5. In a preferred embodiment a water flow rate of 200-250 kg/hr for a 1,000 kgs/hr used tire feedstock is optimal. A slight discharge of excess steam in the scrubber 8 permits the adjustment of the amount of vapor in the condensation process and the temperature of the combined-cycle steam with after-burning of the off-gas in the furnace 62. The water in the steam coming from the scrubber has an increased pH ≥ 8.5 (alkaline) and therefore in this preferred embodiment of the invention the steam generator is constructed of corrosion-resistant stainless steel. In addition, the direct gas pipes are of the type that provide for open access as illustrated in Figure 4D for the purpose of cleaning the pipes from soot, which is present in the off gases and accumulates in the pipes during the combustion of the pyrolysis fuel.

[00150] By way of illustration, using waste tires as feedstock material, as illustrated in this preferred embodiment, the process is equipped with a Venturi mixing condenser 7 for producing liquid fuel from hydrocarbon fractions contained in the gaseous pyrolysis products. The Venturi technique is widely known and familiar to persons in the industry and is based on spraying water in a high-speed gas flow which creates a fine mixture between the streams. From the embodiment illustrated in Figure 1A using used tires as feedstock material, the mix from a 1,000 kg per hour reactor of the combined-cycle thermal decomposition products is as follows:

[00151] Used steam with pyrogas flow at a temperature of 400 degrees C-450 degrees C from reactor (300-350 kg/hr of steam and approximately 600 kg/hr of gaseous hydrocarbons per 1,000 kgs/hr of used tire feedstock).

[00152] Water spray (200-250 kg/hr), which in a preferred embodiment is not to be used from the scrubber, but from a separate container, so as not to contaminate the fuel with sulfur contained in the scrubber water;

[00153] A Steam jet flow of 200-250 kg/hr at a pressure up to 5 bars and temperature up to 150 degrees C is required for atomization of the water spray (the steam pressure is also required to overcome the hydraulic resistance of the coiled super heater at the same time) The length and diameter of the coiled pipe is readily determinable by those familiar with the art.

[00154] The Venturi mixing condenser 7 of this disclosure serves to condense combined-cycle fractions into liquid fuel by reducing their temperature to 100 degrees C, due to the cooling of sprayed water. To exclude carryover droplet aerosols contained in the flow of fuel vapor and the remaining gas, a preferred embodiment of a 1,000 kgs/hour capacity invention would include a Venturi mixing condenser built from Stainless Steel SS301 having a condenser column with the following dimensions: a diameter of not less than: $D = 800$ mm and operating height not less $H = 2.5$ meters Sizes of the Venturi tubes inside the condenser, and the diameters of the holes spraying water and steam jet in the pipe are determined by those familiar with the art. To avoid condensation on the walls, the condenser is insulated or has an outer gas shirt with an auxiliary fan 17 set at a temperature above 100 degrees C for circulating the off gases produced to the steam generator. The apparatus will be determined by comparative calculations of the efficiency of the insulation and will be familiar to those knowledgeable in the art.

[00155] The condenser temperature controller 63 regulates the flow of water spray through a control sensor 39 to maintain a temperature of not less than 100 °C which allows only the heavy hydrocarbons to condense (fuel Oil). Also steam in the pyrolysis gas is not condensed and flows into the furnace together with the afterburner light gas fractions of residual hydrocarbons.

[00156] In the preferred embodiment of the invention, cleaning of the impure fuel condensate from the carbon slime, the carbon slime not comprising not more than 2% of the tire pyrolysis rate, is carried out in a Laval Separator. This slime is subject to repeated processing together with the feedstock materials.

[00157] A Fuel level sensor in the condenser 58 regulates the flow of the pyrolysis fuel to the fuel tank 16. For illustration purposes the amount of fuel oil generated in a preferred embodiment of a system processing 1000 kgs/ hour of used tires would be approximately 400-450 kgs/hour. This fuel oil is cooled in a water heat exchanger 30 to about 40 degrees C. Then the fuel oil would be forwarded for centrifugal separation from the sludge (in the form of soot and heavy fuel oil fractions in a Alfa Laval Separator. The amount of sludge would not exceed 20 kgs/hour and would go back for pyrolysis processing together with the used tire feedstock, or for sale for use in asphalt.

[00158] This disclosure includes a scrubber 8 of standard and common equipment in the industry for washing the off gas (mainly from sulfur dioxide SO₂). A pH sensor in the scrubber adjusts the amount of NaOH (caustic soda) to neutralize the acidity of the scrubbing water. A preferred embodiment of the invention would have a scrubber whose performance for washing the flue gas for a 1,000 kgs/hr tire pyrolysis rate would be approximately 10,000 Nm³/hour with an efficiency of gas purification of at least 90% and an emission temperature of the gases emitted into the atmosphere of up to 40 degrees C. The temperature of the off gases at the inlet of the scrubber 8 is approximately 200 degrees C. The scrubber condenses the steam from the reaction chamber 4, the condenser 7 and from the steam generator 6, as well as steam formed during the evaporation of water sprayed into the scrubber. Water is then collected in the scrubber and cooled in the cooling tower 10 for reuse in steam generation. The scrubber 8 is equipped to adjust the flow of water for its regeneration to an amount of water required for the closed cycle gas purification and the generation of vapor condensation. In the preferred embodiment, the maximum regenerating water flow from the scrubber 8 matches the volume of spraying fresh water in the condenser which in general will be a maximum of 5m³/day per 1,000 kgs/hour tire pyrolysis rate. The descent is a special pump 25 common and known in the industry and automatically adjusts the water levels 60 in the evaporator 9.

[00159] This disclosure includes an evaporator 9 which can reduce by up to 10 times the volume of the water concentrate provided from the water released from the scrubber 8. The effect of the evaporator and the steam generator are similar and differ only in the absence of vapor pressure, which in the case of the evaporator 9 is released into the atmosphere. The evaporator 9 is heated from the flue furnace gas released from the steam generator 6 at the temperature range of 200 degrees C to 250 degrees C. Concentrated scrubber water from the

evaporator is periodically controlled by an automatic valve 29 and is regulated by the level of water 60.

[00160] A preferred embodiment of this disclosure includes a Cooling tower 10 common and known in the industry having a capacity of at least 0.75 MW for 1000 kgs/hr of tire pyrolysis rate which provides cooling for the water (allocated for each device in terms of percentage) for the following equipment: scrubber cleaning off gas and vapor condensation (95%), heat exchangers for cooling the production of liquid fuels (1.5%) and cooling of the carbon in the auger discharge from the tubular pyrolysis reactor (3.5%).

[00161] This disclosure includes for the release of pyrolysis gas directly into the atmosphere in the case of an emergency shutdown due to an electrical failure through an emergency stack 32. For this release each reactor has manual gate valves and the emergency stack has a protective cap at the top with igniters. The gas burner can be ignited remotely from below. The gas supply to the igniter is made from a cylinder of liquefied gas, and its ignition from the top can be made remotely using standard spark ignition devices with a self-contained battery source, and for reliability the ignition device is duplicated. The preferred embodiment of the emergency stack has the following dimensions: emergency stack diameter of not more than $D = 400$ mm, chimney height of not above $H = 20$ m. The dimensions in each pyrolysis operation will be determined by persons familiar with the art. From experience, in the event of a shutdown due to mechanical breakdown, the loading of the feedstock material ceases, but the furnace, condenser and steam generator continue to operate enabling release of the pyrogas from the reactors into the condenser 7 and then for burning in the furnace 5. This process will continue for approximately 40-50 minutes at the end of which only water vapor is produced. When this happens the combustion burner automatically goes 100% fuel combustion and can be regulated by regulating the supply of fuel. Condenser fuel continues but only as a heat source nearing 100 degrees C.

[00162] This disclosure includes a continuous steam pyrolysis method which comprises the following steps: feed the material to be pyrolyzed into a reactor 82 carrying out a pyrolysis reaction in a series of reactors 82 contained within a reaction chamber 4 in the presence of a superheated steam flow, wherein the material feedstock to be pyrolyzed passes through one or more blending zones in each reactor. From experience a too low proportion of the blending zones in each reactor will not provide the desired stirring and blending effect required for a thorough and complete penetration by the super heated steam. For this reason, the total length

of the blending zones should preferably range from 5% to 35% of the total length of the proceeding zones.

[00163] The material to be pyrolyzed is heated in the pyrolysis reaction chamber by two methods: The first is by an insulated heating furnace 5 outside the reaction chamber 4 where the circulating off-gases produced from the pyrolysis process are burnt at a temperature of 1000 degrees C to 1100 degrees C which upon entering the reaction chamber 4 are reduced to 800 degrees C to 850 degrees C and after heating the feedstock material exit through the exit opening in the reaction chamber 4 at a temperature of 600 degrees C to 650 degrees C. The second method is by the superheated steam fed into the opening in the third reactor at a temperature of 400 degrees C to 450 degrees C for direct contact with the feedstock material. In the preferred embodiment feedstock material is being processed at the rate of 1,000 kgs/hour, illustrated here, the steam volume required is a maximum of 300 – 350 kgs/hr.

[00164] The material to be pyrolyzed is moved forward from one reactor to the next reactor during the pyrolysis reaction process and by controlling the moving speed, the material to be pyrolyzed can stay in the reactors for a sufficient period of time to complete the desired pyrolysis reaction. The resident time of the material to be pyrolyzed in each of the proceeding zones is substantially equal and the resident time in each of the blending zones is also substantially equal.

[00165] Furthermore, non-gaseous products resulting from the pyrolysis reaction move to the discharge opening in the first reactor and is discharged from there into the material opening in the subsequent reactor and then discharged through the discharge opening into the following reactor through the material opening into that reactor and discharged through the discharge opening for further processing. Generally, the pyro-solid material procedure comprises cooling the solid material, crushing all the solid pieces to fine particles, providing for separation of the steel cord residual wires from the carbon particles by magnetic separation of the residual steel and then grinding the material into the desired particle size for recycling and may include an acid washing process to remove ash from the solid material. The required equipment is well known to the industry and readily available.

[00166] The gaseous pyro-products are continuously discharged during the pyrolysis process through an oil-gas outlet located in either the first or second reactor for further processing in the condenser as described earlier.

[00167] The superheated steam flow can be generated by a superheated steam generator attached to a steam boiler wherein steam is generated in the steam boiler and heated to form superheated steam at a high temperature. The steam can be heated in any appropriate heating system, whether by means of electric heating, fuel combustion or high temperature gas. In the preferred embodiment of this invention, a tubular piping superheated steam generator wrapped around the outer walls of the reactors is used. In this manner the steam produced by the steam generator is fed to the super heater via piping connecting the tubular super heater and the steam generator. In this manner the steam is superheated by the heat generated from the heated air supplied by the furnace without the addition of any additional heating devices, thereby making a more efficient use of energy.

[00168] To explain the invention more clearly, an exemplary embodiment of the invention is described hereinafter with reference to the attached drawings. In the attached drawings, the dimensions of individual components are only provided for reference, but not for reflecting the actual dimensional scale.

[00169] Figure 1A is a schematic illustration of the preferred embodiment of the process flow of the feedstock material, the by-products produced from the pyrolysis process, together with process flow of the hot air and steam produced by the furnace and steam boiler through the methodology and apparatus of this invention providing for twice the capacity by the use of a two-set pyrolysis process, having one-set of supplementary equipment for cooling and exhaust gas cleaning. The particulars of the process and the apparatus are more particularly described in the Description of the Preferred Embodiment section herein.

[00170] Figure 1B is a schematic illustration of the preferred embodiment of the control and monitoring methodology for one set of the apparatus process which is more particularly described in the Description of the Preferred Embodiment section herein.

[00171] Figure 4A are schematic illustrations of the preferred embodiment of the housing form for the reaction chamber 4. This embodiment of the reaction chamber includes a chamber to house triple screw reactors 81 and side and end walls of the housing of the reaction chamber 4 containing portals to support the triple reactors 82. The housing form of the reaction chamber 4 containing a portal for the heated air input into the triple screw reaction chamber 81 and exit heated air portals 78 from the triple screw tubular reaction chamber 81. The housing of the reaction chamber consisting of a porous castable refractory

consisting of vermiculite – fireclay – alkaline content lined with an inner layer of fireclay concrete with a steel outer case.

[00172] Figure 4B is a schematic drawing representing an alternate embodiment of the housing form for the reaction chamber 4 which encases the furnace and steam boiler. This embodiment of the reaction chamber 4 includes a chamber for a hot air furnace 80, a chamber for the steam boiler 79, and a chamber for the triple screw reactors 81 and side and end walls of the reaction chamber 4 containing portals to support the triple reactors 76. The housing form of the reaction chamber 4 containing a portal for the heated air input 75 into the triple screw tubular reaction chamber 81 from the hot air furnace chamber 80 and heated air exit portals 78 from the triple screw tubular reaction chamber 81 into the boiler chamber and boiler 79 and then out from the boiler chamber through an exit portal 76 to a scrubber 8. The reaction chamber 4 being constructed with a porous castable refractory consisting of vermiculite – fireclay – alkaline content lined an outer casing of steel (steel outer case of reaction chamber not illustrated), the inner layer of fireclay concrete in the hot air furnace chamber 80 which is also not illustrated.

[00173] Figure 4C illustrates a preferred embodiment of a steam pyrolysis system which comprises a reaction chamber 4 containing three reactors 82 installed one above the other, each having a charge opening and a discharge opening which are connected to each other and loading and unloading hoppers 2. Each of the reactors 82 is provided with one axial transporting structure 92 and each transporting structure 92 is connected to a corresponding driving device 87. Each of the transporting structures comprises of a plurality of spiral segments 94 and a plurality of paddle segments 95. Feedstock material is fed through the charge opening of the upper reactor 82 and into the reaction chamber 83 and pyrolyzed therein. The pyro-oil-gas is discharged out through the pyro-oil-gas outlet located in the second reactor, while pyro-solid-materials by-products are fed from the first reactor into the second reactor and the third reactor and discharged out the discharge opening in the third reactor and the reaction chamber.

[00174] Figure 4D illustrates the feedstock materials decomposition process with pyrolysis gases and steam flow through the reactors. The materials are loaded through a charge opening in the first tubular reaction chamber into the first reactor 82 and gradually moved forward by rotating the transporting structure providing a heating and pyrolysis processing zone in the method of this invention along the central axis of the transporting structure. During the

pyrolysis reaction the volatiles from the feedstock materials and carbon black 89 are released. During the transporting course the feedstock materials stay temporarily in the paddle segments 95 to be stirred and blended by the rotating paddles 95 of the paddle segments providing a blending zone in the method of this invention.

[00175] Figure 4E is a cross sectional view of an embodiment of a pyrolysis reaction chamber for implementing the blending method of this disclosure and illustrates pyrolysis reactors 82. The pyrolysis reactors 82 comprise a tubular reaction chamber 83, a driving device 87, an input opening, a pyrolysis gas with steam outlet, a discharge outlet and a communicating opening between the reactors 82. The tubular reaction chamber 83 which functions as a reactor for carrying out the pyrolysis process and the method of this disclosure comprises a first reactor 82, a second reactor 82 and a third reactor 82 installed one above the other which communicate with each other through the communicating openings. Each of the reactors 82 encompasses one axial transporting device 92 and each transporting device is connected to a driving device 87 by a chain wheel devices 84 connected from the central driving device 87 to the other axial transporting devices located in the upper and lower reactors. Each of the transporting devices 92 has a central axis and comprises a plurality of spiral segments 94 and a plurality of paddle segments 95. The total length of the spiral segments 94 and paddle segments 95 are respectively calculated by summing the length of each segment along the direction of the central axis 96. Generally the total length of the paddle segments 95 of each transporting structure 92 ranges from 5% to 35% of the length of the transporting structure 96.

[00176] Figure 8 is a cross section view of an embodiment of a piping section implementing a method to disassemble and subsequently clean the piping system of this disclosure. An illustration of the structure of the piping system contains a removable end cap 98, a gasket 99 and pipe end 100 having a pass through portal and holes to screw and secure and unscrew bolts 97 which hold the removable end caps 98, gaskets 99 and pipe ends 100 in place. The piping consists of straight segments having a pass through ability in each pipe segment and avoids the use of piping elbows which would hinder the ability to clean the build-up of tar emanating from the off-gas.

[00177] In summary this method of this disclosure is unique in that:

[00178] The method and apparatus of this disclosure incorporates a condenser which serves to condense combined-cycle hydrocarbon gaseous fractions into liquid fuel with a yield temperature of not less than 100 degrees C, the cooling to be accomplished by the use of sprayed water mixing with the gases and being it sprayed by a high-speed steam jet. This prevents steam condensation and condensed water mixing with the fuel, thereby eliminating the problem in the process of a water solution containing benzene, benzyne and other soluble fractions of the fuel, as well as eliminating the problem of a pyrolysis soot build up and contamination in the condenser. In so doing the entire waste steam including all of these fractions of the reactor can be recycled back to the boiler and efficiently burnt in the furnace.

[00179] The method and apparatus of this disclosure incorporates a Laval Separator for a cleaning of the impure fuel oil condensate. The heavy fuel fractions of the condensate remain in a water-carbon slime which is subject to repeated processing together with the feedstock materials. The light fuel oil is suitable for fueling commercial diesel generators.

[00180] The method and apparatus of this disclosure incorporates a third reactor thereby extending the time exposure of the residue carbon without the use of a lengthier reactor which may be subject to deflection, while at the same time increasing the heat efficiency of the reaction chamber.

[00181] Furthermore the method and apparatus of this disclosure incorporates the following safety features.

[00182] A method of eliminating build up of soot in the piping system by eliminating soot build up in the condenser and a method for providing ease of access to the interior of the piping system for cleaning the piping system on a periodic basis.

[00183] Incorporating an emergency system for discharging the pyro-gas from the reactors in the event of a shutdown of the pyrolysis plant due to a power failure.

[00184] Incorporating a fire suppression system in the event of a fire in the reaction chamber.

[00185] Due to these advantages, the method and apparatus of this disclosure is capable of pyrolyzing waste materials on a continuous basis and producing by products having a better economic value.

Reference number(s)	Description
1	Conveyor feed system for two reactors
2	Hopper valves for loading and unloading of the reactor
3	Screw water-cooled device for discharge of carbon
4	Reaction chamber
5	Furnace Combustion chamber for afterburning of thermolysis gas
6	Steam Generator (boiler)
7	Steam jet fuel condenser (Venturi)
	<u>Components for processing atmospheric emission:</u>
8	Scrubber for cleaning of gas emissions and the condensation of steam
9	Evaporator for concentration of water emissions scrubber
10	Industrial cooling tower closed type
	<u>Components for pre-processing of carbon:</u>
11	Heat exchanger
12-14	Cooling water pumps
15	Pyrolysis oil tank
16	Alfa Laval separator
	<u>Auxiliary and control automation equipment process:</u>
17	Fan for supplying gas to the furnace for post-combustion
18	Air supply fan for afterburning of combustible gas

19	Fuel burner for start-up and for stabilization of post-combustion gases
20	Fan-exhauster for flow of flue gas from scrubber
21	Auxiliary fan for flue gas exhauster
22	Feed pump for water to the boiler-steam generator
23	Fuel feed pump from the condenser
24	Circulating pump to spray water in the scrubber
25	Feed pump for the evaporator scrubber
26	Pump for spraying water in the fuel condensers
27	Electro / solenoid valve for discharging excess steam in the scrubber
28	Emergency cargo valve for relief of pyrolysis fuel gas into the atmosphere
29	Electro / solenoid valve for discharging the concentrate aqueous waste
30	Tube heat exchanger to cool the pyrolysis fuel oil
31	Alarm System for dispensing inert gas (nitrogen) into the reaction hot box
32	Torch Safety in the event of accidental release of thermolysis off-gases
200	Chemical processor

[00186] Table 1: Index of Component Parts introduced in Figure 1A

Reference number(s)	Description
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33 - 47	Temperature sensors
48, 49	Pressure sensors
50 - 56	Flow meter devices
57 - 60	Liquid level sensors
61 - 63	Temperature controllers
64 - 67	Liquid Level controllers
68 - 71	Motor frequency drivers
72	Water pH controller
73-74	Air Traps

[00187] Table 2: Index of Component Parts for Figure 1B

Reference number(s)	Description
2	First and second hopper valves
4	Reaction chamber
82	Reactors (first, ..., Nth), where N is at least two and may preferably be at least three in some embodiments such as shown in Figure 1A
210	Raw material as input feedstock
212	Carbon black output
220	Steam that may be preferably delivered under pressure
222	Heat preferably delivered as heated air
230	Pyrolysis off-gas

[00188] Table 3: Index of Component Parts for Figure 2.

Reference number(s)	Description
2	Hopper valve
110	First dump gate
112	Second dump gate

[00189] Table 4: Index of Component Parts for Figure 3A and Figure 3B.

Reference number(s)	Description
75	Portal for hot air input
77	Porous castable refractory consisting of vermiculite – fireclay – alkaline content lined with inner layer of fireclay concrete – with steel outer case
78	Portal for hot air exit
81	Chamber for triple reactors

[00190] Table 5: Index of Component Parts for Figure 4A

Reference number(s)	Description
75	Portal for hot air input
77	Porous castable refractory consisting of vermiculite – fireclay – alkaline content lined with inner layer of fireclay concrete – with steel outer case
78	Portal for hot air exit
79	Chamber for steam boiler
80	Chamber for the hot air furnace
81	Chamber for triple reactors

[00191] Table 6: Index of Component Parts for Figure 4B

Reference number(s)	Description
82	Triple reactors
83	reaction chamber
84	Chain wheels for other screw reactors
85	Steam super heating coil
86	Screw bearing boxes
87	Reducing motor for central screw rotation

[00192] Table 7: Index of Component Parts for Figure 4C

Reference number(s)	Description
88	Cleaning steam flow
89	Release of volatiles

[00193] Table 8: Index of Component Parts for Figure 4D

Reference number(s)	Description
90	Paddle segments
91	Spiral screw segments
92	Axial transporting structure
93	Reactor
94	Length of spiral screw segments
95	Length of one paddle segment
96	Length of reactor tube segment

[00194] Table 9: Index of Component Parts for Figure 4E

Reference number(s)	Description
97	Bolts
98	Exterior cap
99	Gasket
100	Inner Cap

[00195] Table 10: Index of Component Parts for Figure 8

[00196] This disclosure is related to the detailed technical contents and inventive features thereof. People with ordinary skill and art in this field may proceed with a variety of modifications, variations and replacements based on the disclosures and suggestions of the invention as described without departing from the scope and the spirit of the invention. The preceding embodiments provide examples of the invention and are not meant to constrain the scope of the following claims.

Claims:

What is claimed is:

1. An apparatus, comprising at least one of:
 - a hopper valve adapted to couple to an input and/or an output of a chamber to insure no introduction of oxygen into said chamber; and/or
 - a reaction chamber including at least two reactors adapted to successively process said input to create said output and a pyrolysis off-gas; and/or
 - a condenser adapted to receive said pyrolysis off-gas and adapted to support at least one of
 - maintaining an internal temperature of said condenser at or above 100 degrees Centigrade (C) to keep any low complexity hydrocarbon gas in said pyrolysis off-gas from condensing to contaminate a fuel oil created from said pyrolysis off-gas and/or
 - using water droplets within said condenser to mix with particulates in said pyrolysis off-gas to condense said particulates out of a return gas and into said fuel oil; and/or
 - an orifice adapted to turbulently mix a low BTU gas fuel and steam to create a high BTU fuel mixture; and/or
 - a furnace adapted to interact with said orifice to combine ignition by a high BTU fuel and continuing burning of said high BTU fuel mixture without said high BTU fuel; and/or
 - a chemical processor including at least one of said hopper valve, said reaction chamber, said condenser, said orifice and/or said furnace.
2. The apparatus of Claim 1,
 - wherein said chamber is part of said reaction chamber; and/or
 - wherein said condenser is adapted to support exactly one of
 - maintaining said internal temperature at or above 100 degrees C or
 - using said water droplets within said condenser to mix with said particulates; and/or
 - wherein said return gas includes said low BTU gas fuel; and/or
 - wherein said chemical processor is adapted to create carbon black as one of said output.

3. The apparatus of Claim 1,
wherein said hopper valve is adapted to further receive steam to further insure no introduction of oxygen into said chamber; and/or
wherein said reaction chamber is adapted to receive heated air to process said input and create said output without introduction of oxygen into said input; and/or
wherein said condenser is adapted to support both
maintaining said internal temperature at or above 100 degrees C and
using said water droplets within said condenser to mix with said particulates;
and/or
wherein said orifice is further adapted to received said ignited fuel oil to initiate creating said high BTU fuel mixture; and/or
wherein said furnace includes said orifice; and/or
wherein said chemical processor is further adapted to create said fuel oil as one of said output.
4. The apparatus of Claim 1,
wherein said hopper valve includes a first hopper coupled by a first gate to a second hopper coupled by a second gate to a third hopper, wherein said first gate and said second gate are operated to insure said no introduction of said oxygen; and/or
wherein said condenser uses at least a Venturi Effect to create said fuel oil from said pyrolysis off-gas; and/or
wherein said orifice is further adapted to turbulently mix said return gas including said low BTU gas fuel with said steam to create said high BTU fuel mixture; and/or
wherein said chemical processor further includes
a first of said hopper valve coupled to said reaction chamber to create said input into said reaction chamber,
said condenser adapted to receive said pyrolysis off-gas from said reaction chamber to create said return gas, and
said orifice coupled to said furnace and adapted to receive said return gas to create said high BTU fuel mixture.

5. The apparatus of Claim 4, wherein said second hopper and/or a third of said reactors is operated to introduce steam to further insure said no introduction of said oxygen into said reaction chamber.
6. The apparatus of Claim 1, wherein said input is created from at least one of tires, and/or plastic, and/or human wastes, and/or animal wastes and/or stalks and/or wood and/or grass and/or leaves and/or roots.
7. A method, comprising at least one of the steps of:
operating a hopper valve adapted to couple to an input and/or an output of a chamber to insure no introduction of oxygen into said chamber; and/or
operating a reaction chamber including the steps of
operating at least two reactors to process said input to create said output and a pyrolysis off-gas; and/or
operating a condenser to receive said pyrolysis off-gas and further comprising at least one of the steps of
maintaining an internal temperature of said condenser at or above 100 degrees Centigrade (C) to keep any low complexity hydrocarbon gas in said pyrolysis off-gas from condensing to contaminate a fuel oil created from said pyrolysis off-gas and/or
using water droplets within said condenser to mix with particulates in said pyrolysis off-gas to condense said particulates out of a return gas and into said fuel oil; and/or
operating an orifice to turbulently mix a low BTU gas fuel and steam to create a high BTU fuel mixture; and/or
operating a furnace to interact with said orifice to combine ignition by a high BTU fuel and continued burning of said high BTU fuel mixture without said high BTU fuel; and/or
operating a chemical processor including at least one of the above steps of
operating said hopper valve, and/or
operating said reaction chamber, and/or
operating said condenser, and/or
operating said orifice, and/or
operating said furnace.
8. The method of Claim 7,

wherein said chamber is part of said reaction chamber; and/or
wherein the step operating said condenser includes exactly one of the steps of
maintaining said internal temperature at or above 100 degrees C or
using said water droplets within said condenser to mix with said particulates;
and/or
wherein said return gas includes said low BTU gas fuel; and/or
wherein the step operating said chemical processor further creates carbon black as one
of said output.

9. The method of Claim 7,
wherein the step operating said hopper valve further includes the step of receiving
steam to further insure no introduction of oxygen into said chamber; and/or
wherein the step operating said reaction chamber further includes the at least one of
the steps of
receiving heated air to process said input and create said output without introduction
of said oxygen into said input, and/or
receiving steam in a third and/or subsequent reactor to further create said output
without introduction of said oxygen; and/or
wherein the step operating said condenser further includes both the steps of
maintaining said internal temperature at or above 100 degrees C and
using said water droplets within said condenser to mix with said particulates;
and/or
wherein the step operating said orifice further includes receiving said ignited fuel oil
to initiate creating said high BTU fuel mixture; and/or
wherein the step operating said furnace includes the step of operating said orifice;
and/or
operating said chemical processor creates said fuel oil as one of said output.

10. The method of Claim 7,
wherein operating said hopper valve includes the steps of
operating a first hopper coupled a first gate to a second hopper;
operating said first gate;
operating said second hopper coupled by a second gate to a third hopper;
operating said second gate;

wherein the steps operating said first gate and said second gate insure said no introduction of said oxygen; and/or

wherein the step operating said condenser includes the step of using at least a Venturi Effect to create said fuel oil from said pyrolysis off-gas; and/or

operating said orifice further includes the step of turbulently mixing said return gas including said low BTU gas fuel with said steam to create said high BTU fuel mixture; and/or

wherein the step operating said chemical processor further includes the steps of

operating a first of said hopper valve coupled to said reaction chamber to create said input into said reaction chamber,

operating said condenser to receive said pyrolysis off-gas from said reaction chamber to create said return gas, and

operating said orifice coupled to said furnace and adapted to receive said return gas to create said high BTU fuel mixture.

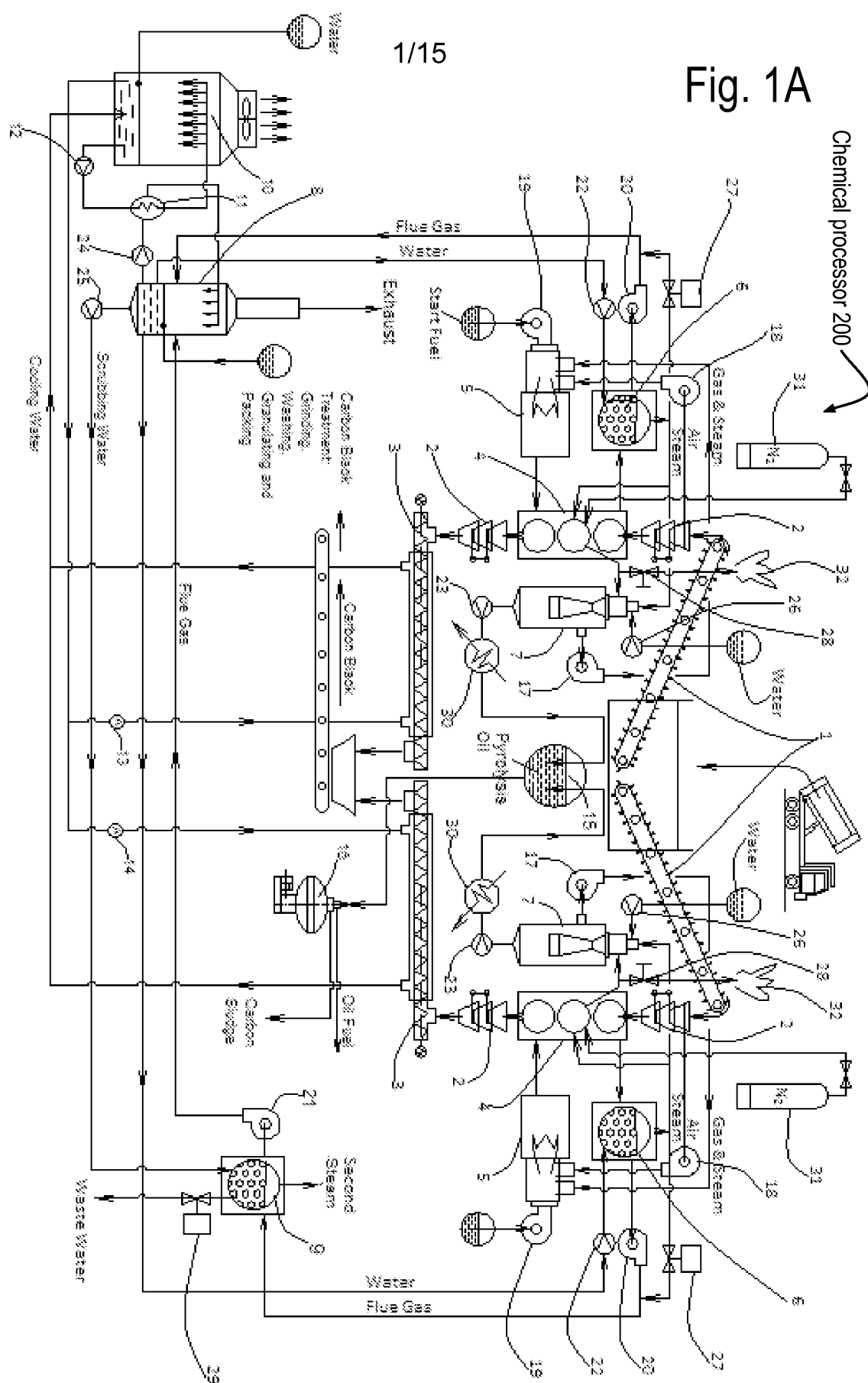
11. The method of Claim 10, wherein the step operating said second hopper further includes the step of introducing steam to further insure said no introduction of said oxygen; and/or

wherein the step operating said reaction chamber further comprises the step of operating a third of said reactors to receive said steam to further insure said no introduction of said oxygen.

12. The method of Claim 7, further comprising step of creating said input from at least one of tires, and/or plastics, and/or human wastes, and/or animal wastes and/or stalks and/or wood and/or grass and/or leaves and/or roots.

13. The method of Claim 7, wherein the step of operating said condenser insures removal of a possibility for dioxin contamination as one of said output.

Fig. 1A



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Fig. 1B

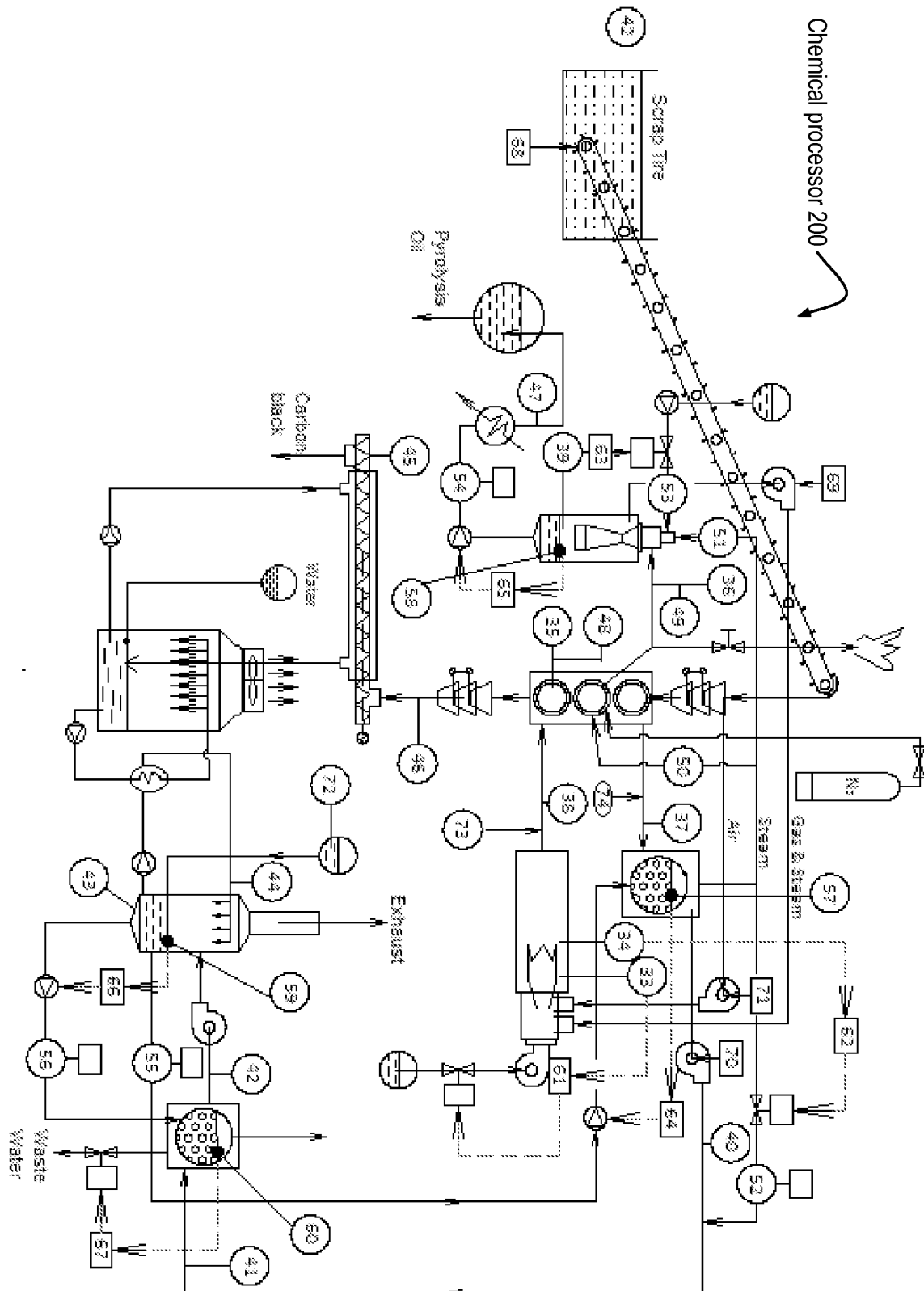


Fig. 2

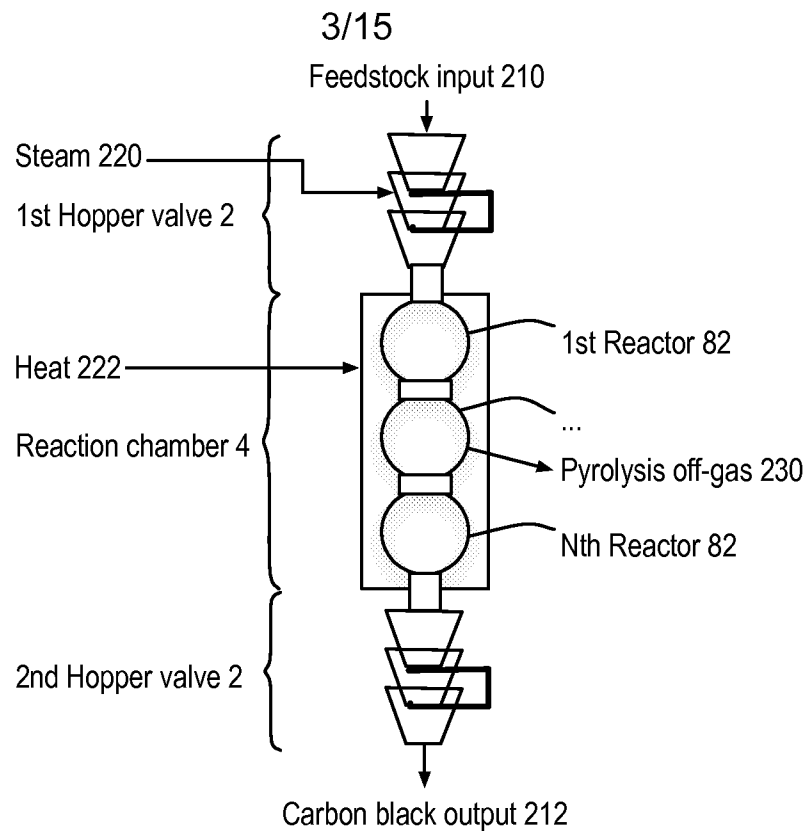


Fig. 3A

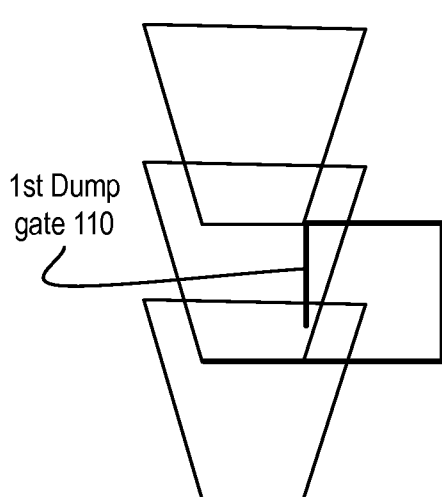


Fig. 3B

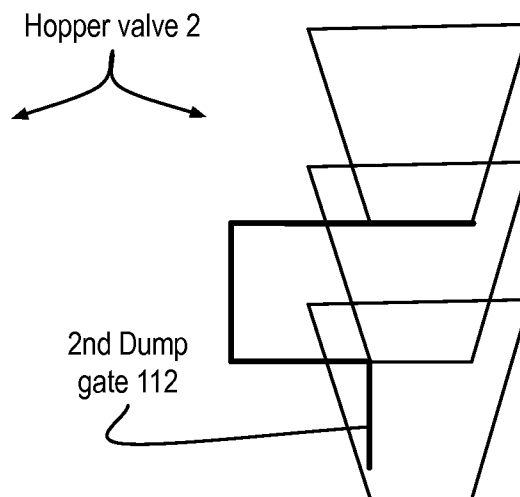


Fig. 4A

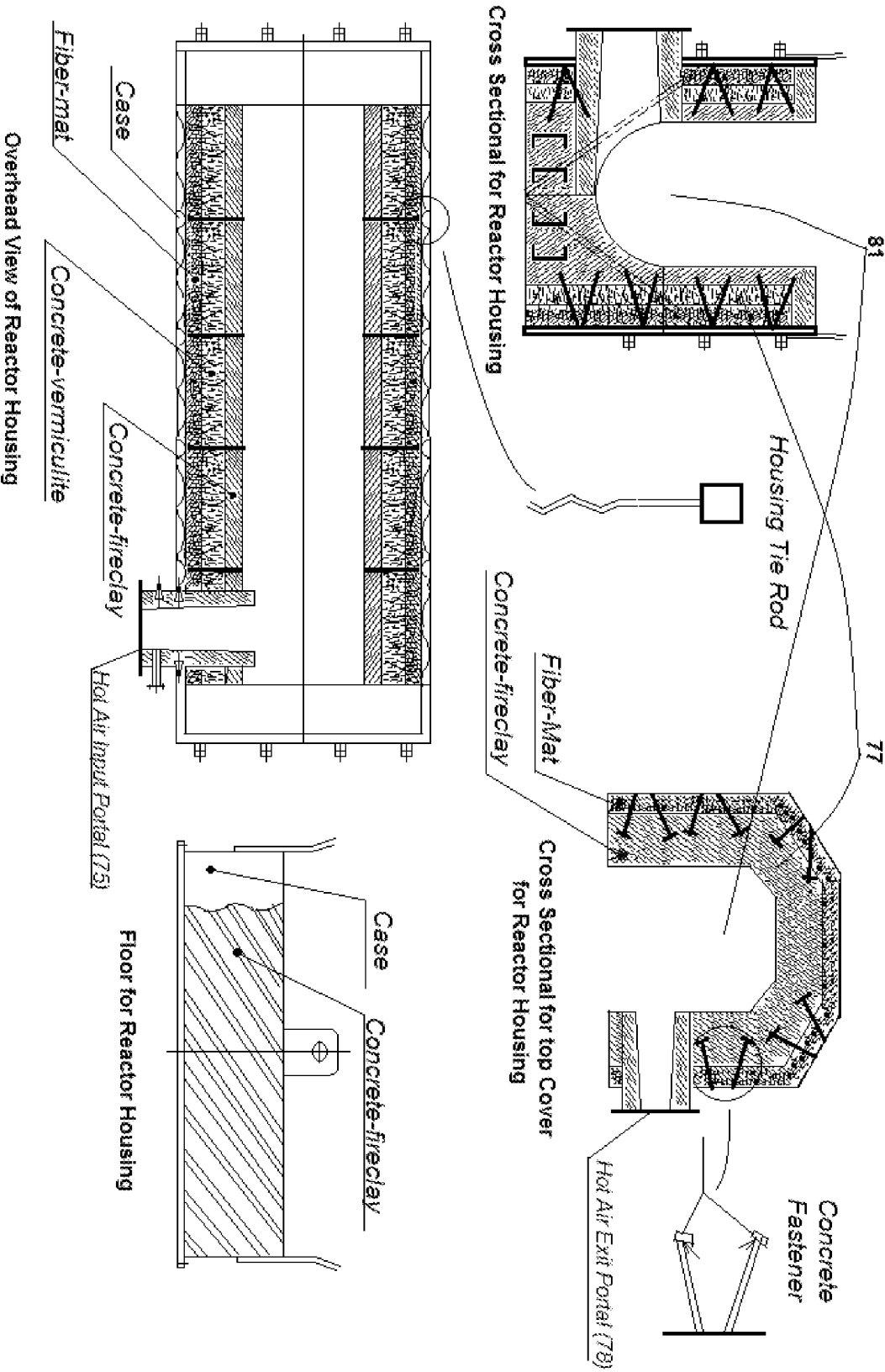


Fig. 4B

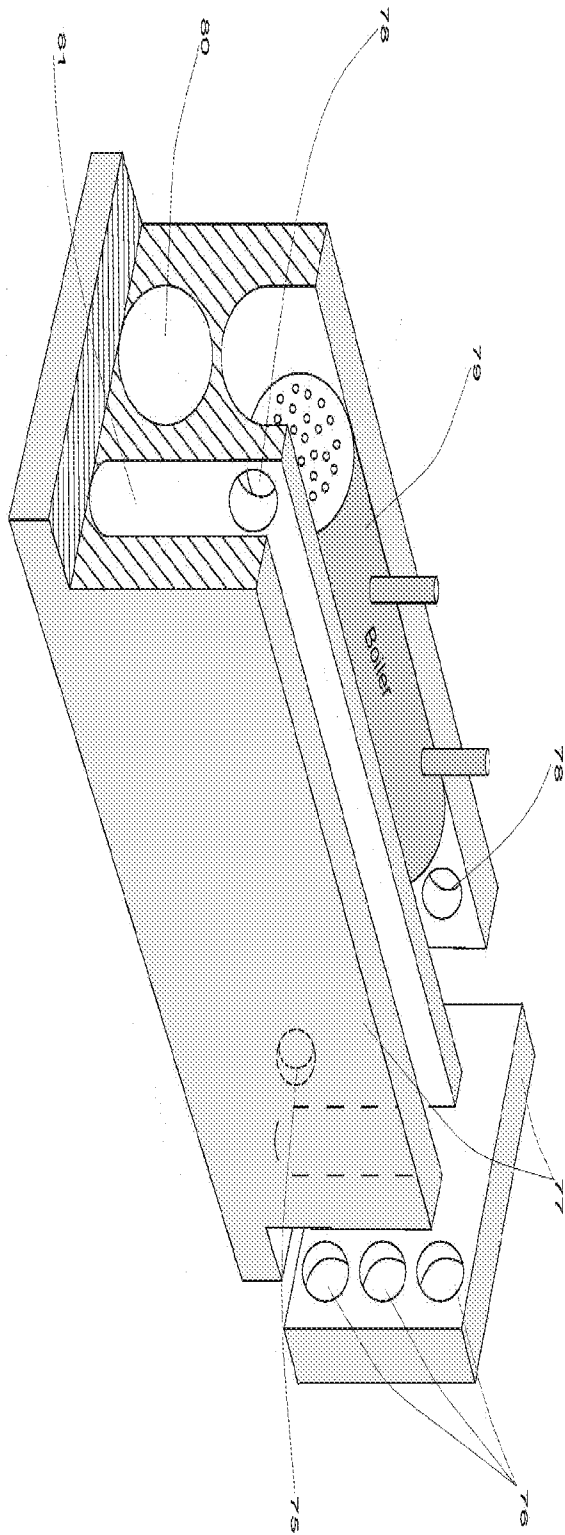


Fig. 4C

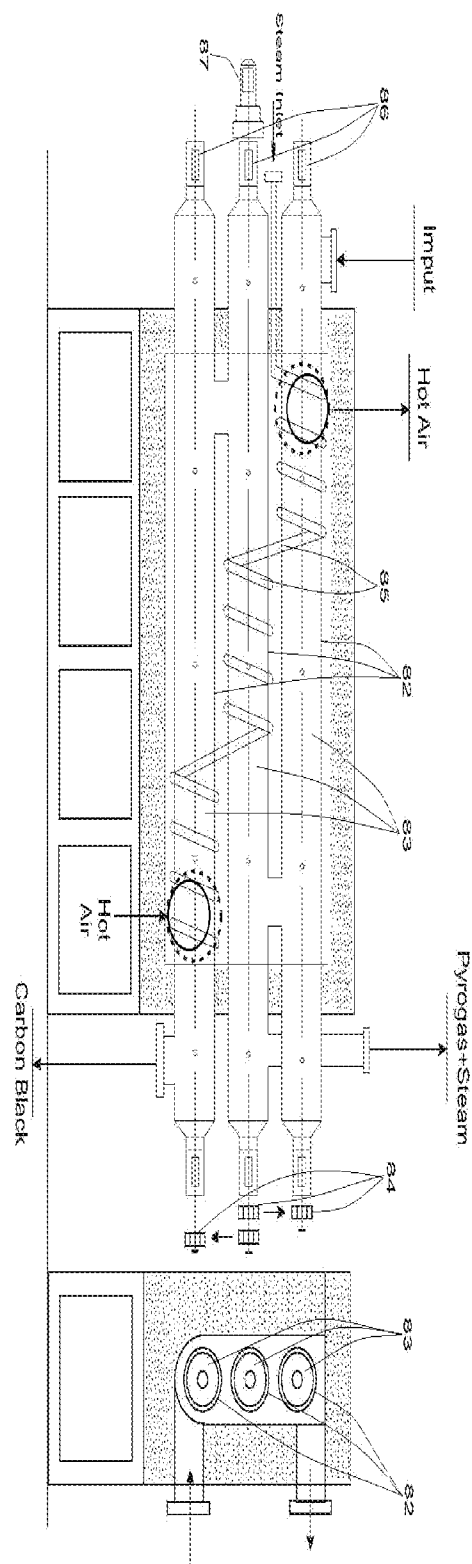


Fig. 4D

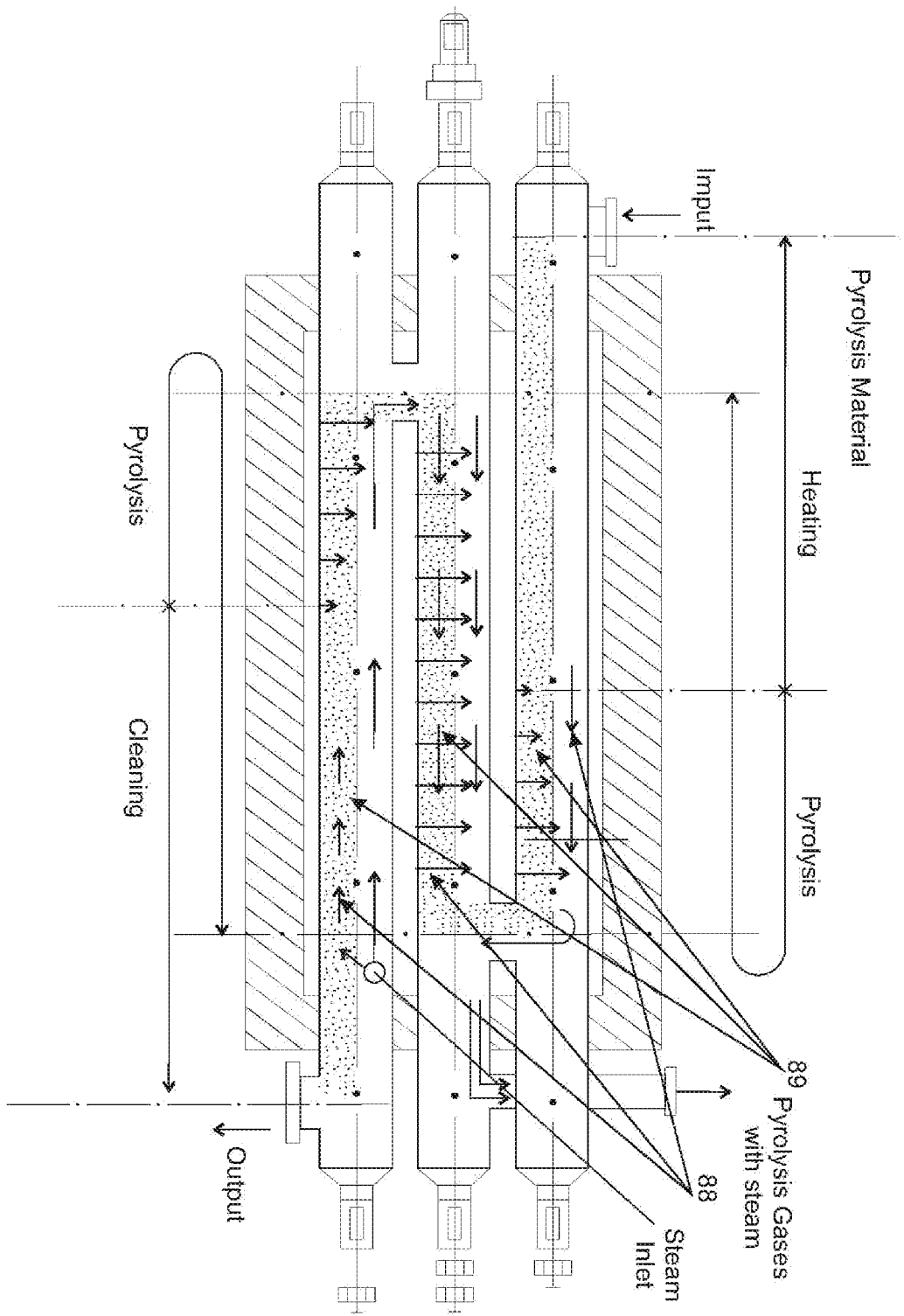
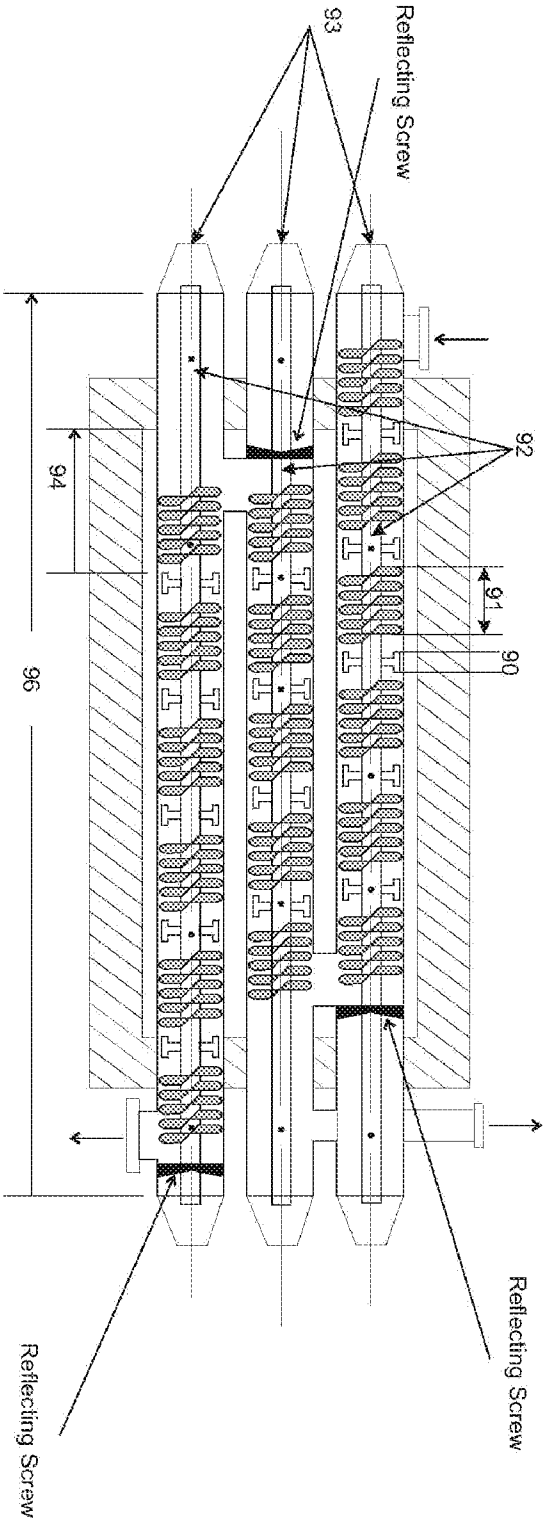


Fig. 4E



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Fig. 4F

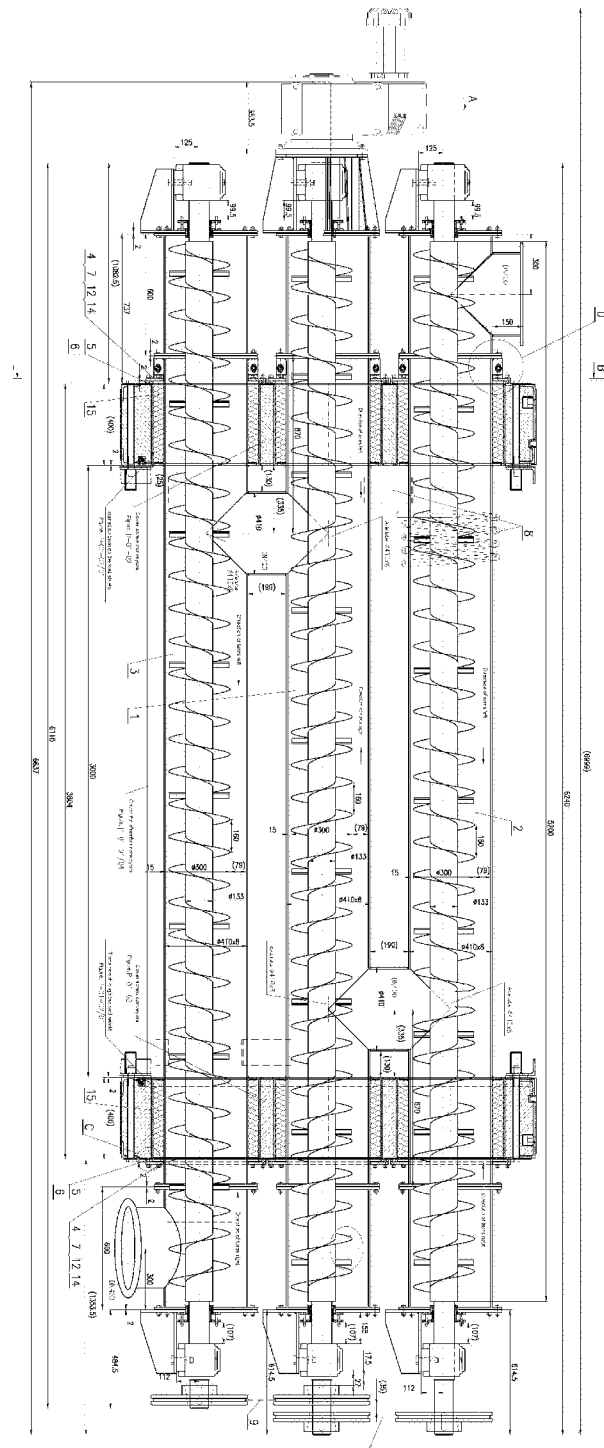


Fig. 5B

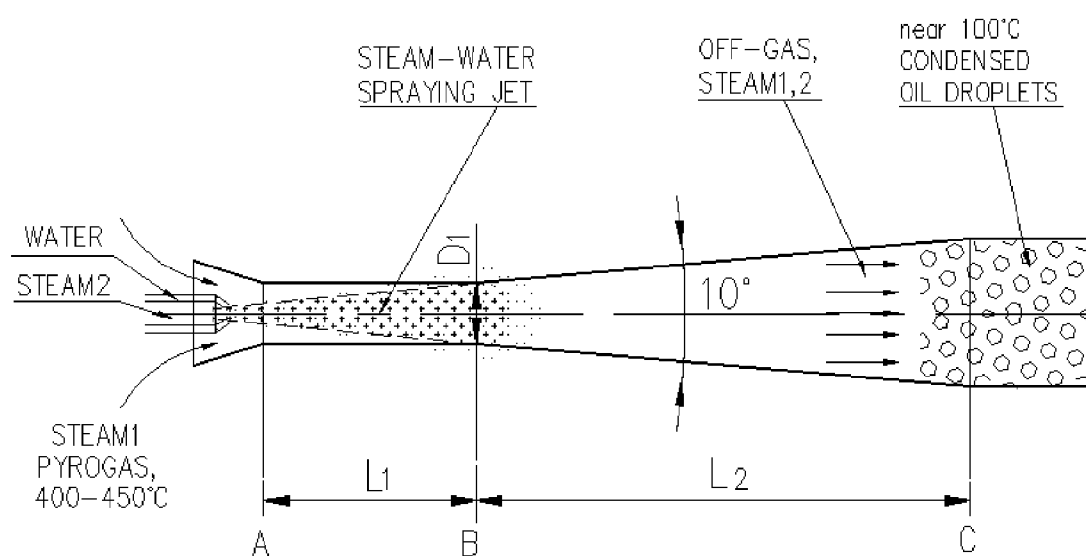


Fig. 6

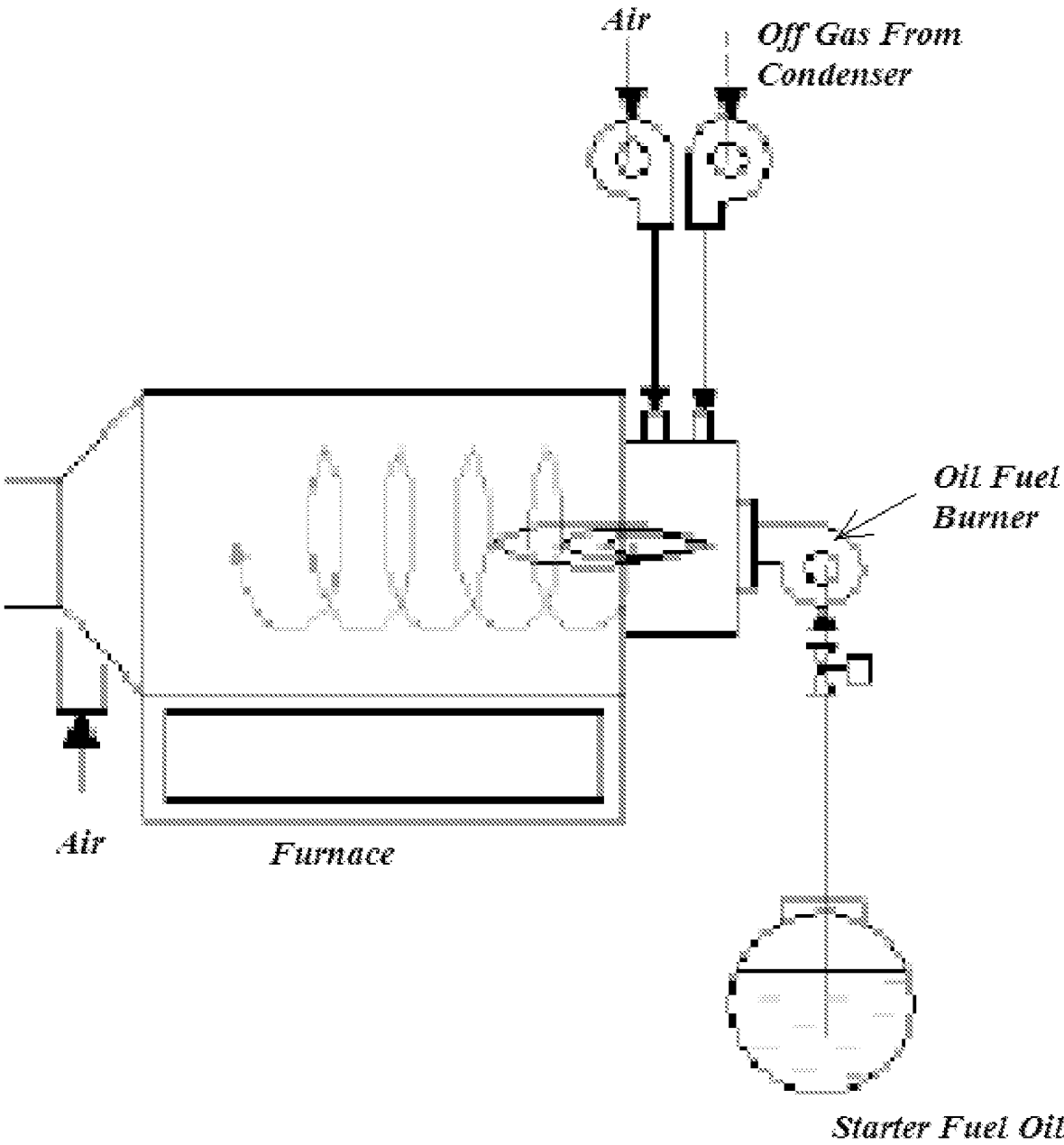
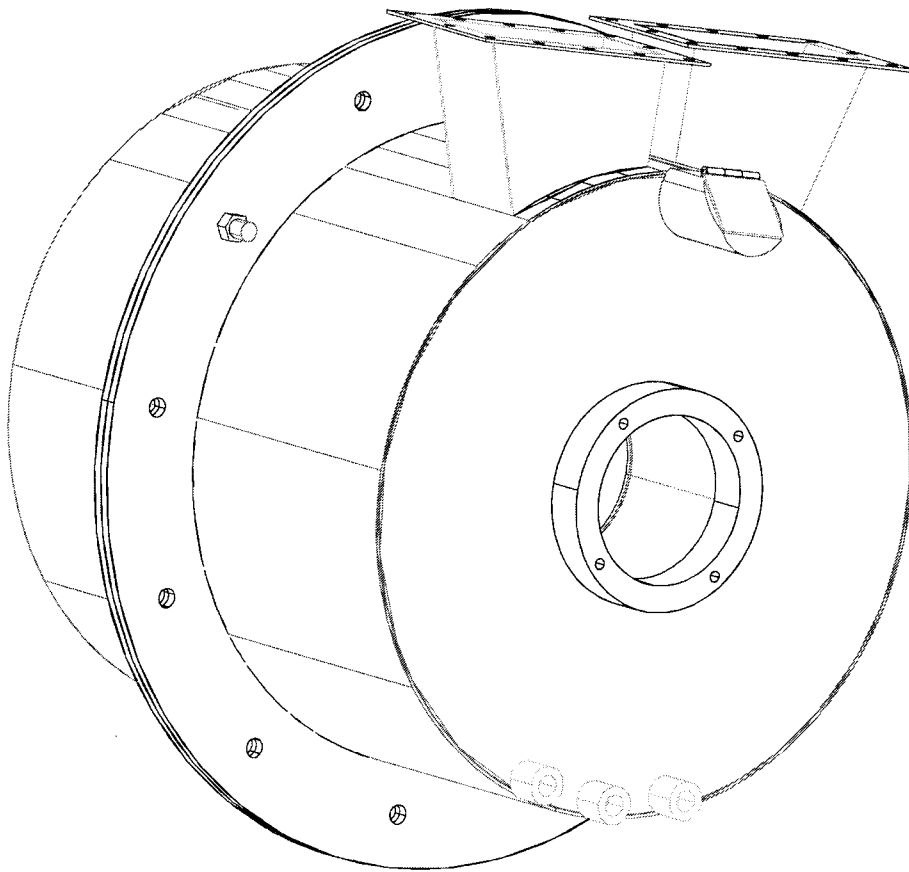


Fig. 7A



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Fig. 7B

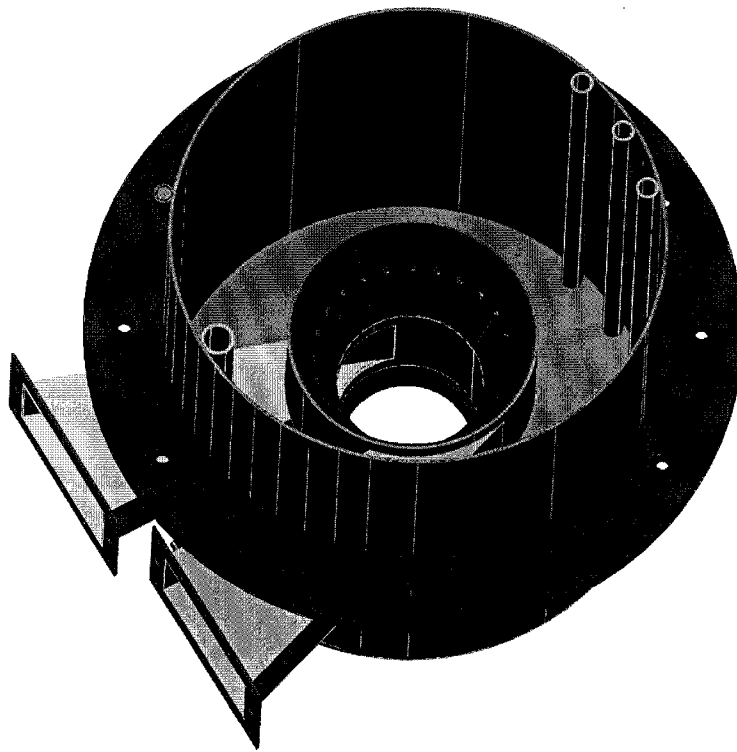


Fig. 7C

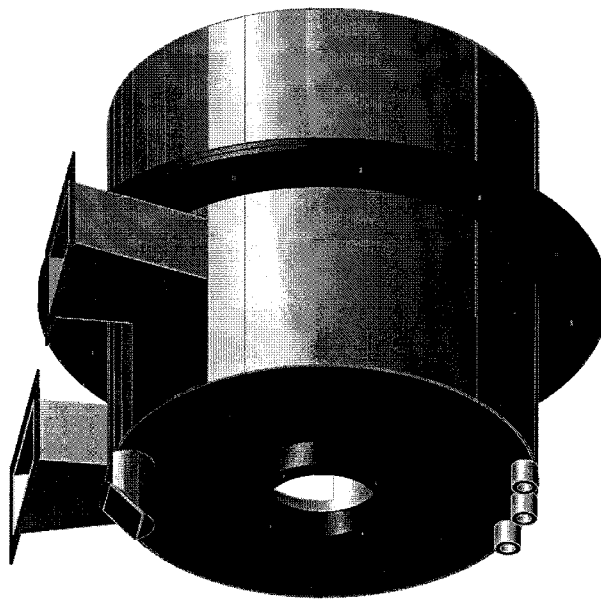


Fig. 8

