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(71) **Applicant** *(for all designated States except US)*: **FLSMIDTH A/S** [DK/DK]; 77 Vigerslev Alle, DK-2500 Valby (DK).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **SCHMIDT, Iver** [DK/DK]; Sdr. Kirkevej 16, DK-9520 Skørping (DK). **RASMUSSEN, Jørn Møller** [DK/DK]; Frederiksdalsvej 113, DK-2830 Virum (DK). **PAONE III, Peter T.** [US/US]; 2040 Avenue C, Bethlehem, Pennsylvania 18017 (US). **SALMENTO, John S.** [US/US]; 2040 Avenue C, Bethlehem, Pennsylvania 18017 (US).

(74) **Agent**: **DEJOSEPH, Daniel**; 2040 Avenue C, Bethlehem, Pennsylvania 18017 (US).

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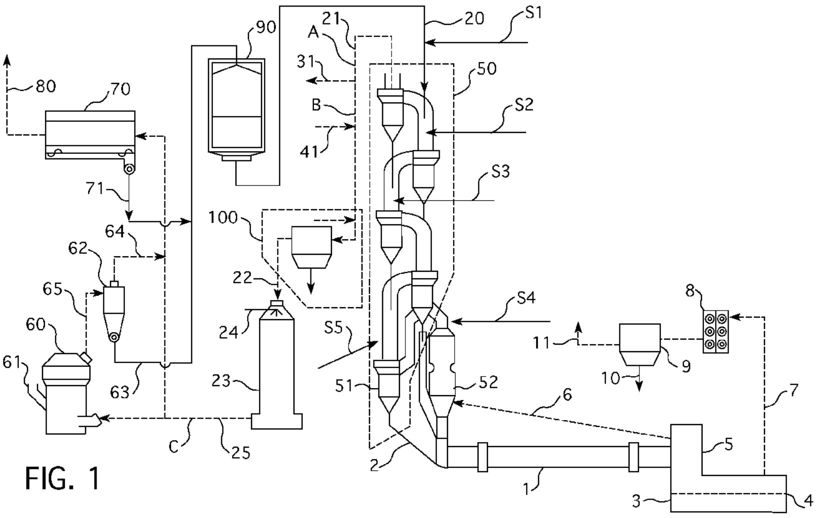

FIG. 1

(57) **Abstract**: Disclosed is a method and apparatus for the reduction of organic compounds and other emissions from an industrial plant utilizing a cement or minerals kiln that has a high level of organic compound emissions. The invention consists of a filter for the control of particulate emissions which has been treated with a catalyst to provide catalytic destruction of gaseous emissions as process gases are passed through the porous medium of the filter.

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POLLUTION CONTROL SYSTEM FOR KILN EXHAUST

Iver Schmidt
Jørn Møller Rasmussen
Peter Paone
John Salmento

Background of the Invention

There is an increasing level of awareness concerning the emission of certain volatile organic compounds (VOCs), combustion byproducts such as carbon monoxide and NO_X, and dioxin/furans from industrial plants such as cement manufacturing facilities. With this heightened level of awareness, more stringent environmental regulations are being adopted to ensure low emissions from these industrial plants. In some cases, the level of emissions currently experienced may not be adequately reduced using existing technologies in order to meet new environmental regulations. In other cases, existing technologies for emissions controls in other applications are prohibitively costly in industrial applications. Consequently, there is an interest in developing new systems for controlling these high levels of emissions to meet newly proposed regulations, and that is an object of the present invention.

Very few cement and lime kilns have installed specialized controls for emissions of organic compounds. Cement kilns in the United States have attempted the use of Regenerative Thermal Oxidizers (RTOs), such as those devices described in US 5,352,115 and US 5,562,442. These devices subject the process gases to intense oxidizing conditions produced by applying a direct heat source and introducing air to the system in order to incinerate the organic compounds in the gas stream. The exhaust gases are heated to a temperature in excess of 800^oC, and much of this heat is recovered through the system and used for preheating the gas stream prior to the combustion region. The devices require a clean fuel for heating, as soot and ash introduced from the fuel can reduce the thermal efficiency of the unit. These devices are of limited applicability in use with cement and minerals processing systems for several reasons – they are small in size relative to the process gas stream that must usually be treated (requiring multiple, parallel units), the intense oxidizing conditions produced in the unit can oxidize SO_2 present in the gas stream to SO_3 (which necessitates the use of a wet limestone scrubber or other SO_2 control device prior to the RTO), and the use of additional fuel firing for operation will increase emissions of carbon monoxide and carbon dioxide. Combined, these disadvantages make RTOs very difficult to install in industrial plants such as cement kilns because of the large space required for the RTO and supporting equipment, the high cost of installation, and the high cost of operation.

An alternative approach that may be attempted is the use of catalytic means of the destruction of organic compounds and carbon monoxide. Catalyst applications in cement kiln systems have generally been targeted towards the removal of nitrogen oxides through "Selective Catalytic Reduction", but the art of using catalysts in similar applications for the removal of organic constituents may also be practiced, as in US 6,156,277. In this method, the exhaust gas from a cement kiln is directly passed through a reduction catalyst for the destruction of the emissions from the kiln system. The temperatures required for the chemical reactions for the destruction of NOx and other emissions products is generally between 250 °C and 450 °C in practice, although wider temperature ranges are available with specific designed catalysts. In a typical cement kiln process, the exhaust gas from a preheater/precalciner system is typically in such a range. While this temperature range is conducive to a high activity for the catalyst, these systems often see issues associated with the loading of particulate matter in the exhaust gas stream. Typical dust loadings in these gas streams may be in the range of 20 to 50 grams of particulate per cubic meter of exhaust gas, although dust contents exceeding 150 grams of particulate per cubic meter of exhaust gas can be seen. The particulate matter is typically comprised of the fine dust fraction of feed material introduced to the kiln system which is not completely captured within the kiln or preheater system. This fine dust is comprised of varying amounts of and compositions containing calcium, aluminum, silica, and iron, as well as sodium, potassium, chlorides, sulfur and minor constituents such as phosphorous, arsenic, thallium, and zinc. Depending on the catalyst structure in use, any of these compounds can cause degradation of the catalytic effect of the system through de-activation of the surface, poisoning of the catalyst, erosion of the catalytic surface, or the blocking of the catalyst surface from contact with the gaseous constituents. In addition, the dust content of the gas stream requires larger openings in the catalytic structures in use in these systems, requiring larger catalyst structures to obtain the same catalytic surface as is found in other industrial applications. In systems where SCR is practiced, soot blowers for dedusting and periodic cleaning of the catalyst surface are required. The loss in efficiency associated with dust loading therefore leads to higher costs for these systems for design and operation than in comparable industries with low dust loads.

As an improvement over these "high dust SCR" applications, systems have been proposed which include a step for removal of the dust present in these industrial applications prior to the catalyst structure. These systems comprise an additional cleaning step utilizing a dust filter or a precipitator prior to the catalytic structure, such as is described in US Application 2010/0307388. In this arrangement, the gases coming from a cement kiln system are first passed through a dust precipitation system to remove particulate matter. The gases are then passed through the reduction catalyst for destruction of the targeted pollutants. After treatment in the reduction catalyst, the hot gases may then be used in other devices found in the industrial facility, such as grinding mills, and vented through a stack. This "low dust SCR" arrangement offers several advantages over the "high dust SCR" arrangement, including a longer lifetime for catalyst structures before replacement, the usage of smaller openings between catalyst plates or honeycombs which allows for a smaller and less costly catalytic structure, and lower operating costs associated with less replacement of catalyst. This arrangement does come with several disadvantages. The requirement for a dust collection device such as a filter or precipitator is an added piece of process equipment that comes with installation and long term operating and maintenance expenses. The additional pressure drop through the precipitator or filter, in addition to the catalyst structure, will increase the power requirements on any fans utilized for drafting gas through the overall system. In addition, the layout requirements of the cement kiln or minerals processing facility will often make it difficult or impossible to fit both the filter or precipitator and a catalytic structure within the confines of available areas for installation.

In view of the prior art issues, the objects of the present invention include improving the control of various undesirable emissions from cement and minerals, and obtaining a high efficiency of catalytic activity such as is found in a "low dust SCR" applications while having a high inlet dust loading similar to that encountered in "high dust SCR" applications, while utilizing fewer pieces of equipment and a lower pressure drop than a "low dust SCR" system.

Brief Description of the Invention

The above and other objects are achieved by utilizing a device fitted with a filter element or filter elements which are pretreated with the catalyst or composed of the catalytic materials dispersed through the filter elements.

According to the invention, there is a method for the reduction of organic compounds and other emissions from an industrial plant having a cement or mineral kiln or calciner system that has a high level of emissions. The invention treats the exhaust gas stream from the cement or minerals processing plant on a filter medium in order to remove entrained particulate, and destroys the targeted pollutant within the structure of the filter medium. Particulate captured on the surface of the filter medium is periodically removed from the surface of the medium to prevent blockage of the porous filter medium and to avoid undesireable increases in energy consumption at the processing plant. Such removal can be achieved by a number of methods, including subjecting the filter medium to sonic or ultrasonic vibration or the mechanical removal of particulate matter with a solid object. Pre-treatment of the exhaust gas stream can be used to enhance the pollutant destruction capabilities of the filtration device, or to prevent oxidation of entrained pollutants to less desirable compounds. This invention is not limited to cement or lime plants. It can be used in any industrial processing plant where the emission of organic compounds, total organic carbons or volatile organic carbons, carbon monoxide, nitrogen oxides, or dioxin/furans require a very high degree of treatment for attainment of regulatory requirements, such as, for example, in plants that use long dry cement kilns, short cement kilns with precalciners, and lime kilns.

Description of the Drawings

FIG. 1 is a diagram of a plant for the production of cement clinker adapted to the cleaning of hydrocarbons and other contaminants according to the invention.

FIG. 2A is a diagram of one embodiment of the invention in a cement or minerals kiln system.

FIG. 2B is a more detailed view of a filter element utilized in the invention.

FIG. 3 is a diagram of another embodiment of the invention utilizing a different method for holding and supporting the catalytic filter elements.

FIG. 4A is a diagram of another embodiment of the invention utilizing another method for holding and supporting the catalytic filter elements and for removal of the collected particulate matter.

FIG. 4B is an isometric view of the embodiment of the invention depicted in FIG. 4A.

FIG. 5 is another general diagram of a plant for the production of cement clinker adapted to the cleaning of hydrocarbons and other contaminants according to the invention.

FIG.6 is an example of organic compound reduction curves comparing removal efficiencies of the invention at varying temperatures and for various organic compounds.

Description of the Invention

Although the invention is particularly directed to the reduction in emissions of organic compound emissions, the present invention also applies to the removal of other products of incomplete or partial combustion such as carbon monoxide, condensable VOC's, nitrogen oxides, and dioxin/furans that contaminate manufacturing processes. Many of the organic compounds that this invention is directed towards fall under numerous overlapping categories of compounds, such as Total Organic Carbon (TOC), Total Hydrocarbons (THC), and Volatile Organic Compounds (VOC), and this invention is broadly aimed to the various compounds which are classified under these general categories. Also, while emphasis is placed on a cement manufacturing process, the present invention is applicable to other minerals and kiln manufacturing processes, such as lime manufacturing processes and other industrial processes where very high starting emission levels of these contaminate compounds can not be sufficiently controlled using existing methods, or where existing methods of control are cost prohibitive.

Emissions of organic compounds from industrial process may originate from a variety of different sources within a system. In minerals processing systems such as cement kilns, these sources may include incomplete combustion of fuels fired within the system, decomposition or partial combustion of organic species within feed components, contamination of gas streams with organic materials such as from oiled-compressors, introduction of organic components in process water used for cooling, and from introduction of ambient air which may contain organic components in small quantities. Also, the oxygen concentrations at the exhaust of many industrial processes such as cement kilns are kept low in order to improve efficiencies within the systems, but such low oxygen concentrations inhibit full combustion of these various organic compounds prior to release from the system. These minor components may contribute to localized conditions such as smog, and are therefore seeing increased levels of regulation.

The invention in part comprises the use, in conjunction with a kiln exhaust, of a device fitted with a filter element or filter elements which are pretreated with the catalyst or composed of the catalytic materials dispersed through the filter elements. The catalyst utilized in the pretreatment or the construction of the filter element is chosen prior to installation of the filter elements within the device in order to treat those gaseous emissions within the exhaust stream from the industrial process which must be controlled in order to achieve regulatory compliance. While the catalysts are designed for the control of organic compound emissions such as Volatile Organic Compounds (VOC), Total Hydrocarbons (THC), Total Organic Carbon (TOC), and similar classifications of emissions, the catalyst for the pretreatment of the filter elements or the dispersal through the filter elements may also be chosen for the reaction or destruction of other compounds including dioxins, furans, carbon monoxide, or oxides of nitrogen (NO_X), or can be used for the oxidation of mercury for further treatment and capture after the device. The catalytic elements used in the treatment or manufacture of the filter elements can contain a mixture of any of vanadium, platinum, palladium, ruthenium, titanium, lanthanum, cerium, yttrium, zirconium, tungsten, manganese, niobium, molybdenum, nickel, iron and copper in compositions designed to remove those emissions which must be reduced in the gas stream.

The filter elements are porous membranes which allow for the passing of exhaust gases through the elements, but of sufficiently small pore size to capture a significant quantity of the dust on the surface of the elements which is exposed to the process exhaust gas containing entrained dust. The surface of the filter element exposed to the process exhaust gas containing entrained dust is referred to as the “dirty side” of the filter element, while the surface of the filter opposite the “dirty side” and through which the dedusted process gases pass to the outlet of the filter is referred to as the “clean side” of the filter elements. The filter element is comprised of the porous substrate as well as the catalytic component of the filter element during the manufacturing process. The filter elements are treated with the catalysts either in whole or in part, with catalysts deposited on both the “clean side” surface and the “dirty side” of the filter element penetrating through a depth to the inside of the filter element, with the maximum penetration of the catalysts being through the entire thickness of the filter element, i.e. from the “clean side” to the “dirty side” of the filter element. In all cases, it is preferred not to have the catalysts applied only to the “dirty side” of the filter element, as this exposes the catalyst to the dust particles which may erode or “poison” the catalyst and reduce its lifetime. The non-catalytic portion of the filter element, which serves as a substrate to the catalyst and as the porous filter for entrained dust in the gas stream, is composed of a material which is designed to retain sufficient filtering properties through the design range at which the filter elements will be exposed for filtration of dust and for catalytic reduction of gaseous pollutants. The non-catalytic composition of the filter element may be comprised of any of porous ceramic, glass fibers, ground quartz, alumino-silicate ceramic fiber, rutile, calcite, corundum, kaolinite, and diatomaceous earth, among others.

The surface of the filter elements which is exposed to the process exhaust gas entering the device is periodically cleaned to prevent excessive accumulations of dust, which would otherwise increase the pressure drop of the device, and thus increase the power consumption of the system in operation. Cleaning of the device may be performed through mechanical cleaning, such as scraping or "rapping" of the filter elements, but is preferentially performed through periodic "pulsing" of gas counter to the flow of the industrial process exhaust gas entering the filter element. Dust which is released from the filter element may be returned to the cement or mineral processing facility, or may be withdrawn and stored for use elsewhere.

The filter element is placed such that the exhaust gases from the cement or minerals industrial process, which contain entrained particulate matter, are passed through its porous filter. The majority of the entrained particulate matter is captured on the surface of the filter element and will not come into contact with the interior of the filter element. Gases passing through the pores of the filter element come in direct contact with the catalytic compounds with which the element has been treated, ensuring contact time between the gas and the catalyst. This reduces the required residence time with the catalyst and allows for the possibility of a smaller installation. By using the filter elements as the catalyst substrate, the steps of separation (of the dust from the gases) and catalytic contact may occur within the same device, also reducing the size and cost of an installation.

By suitable pretreatment or post treatment of the gases around the filter device, additional pollutant controls may be achieved. In one variant of the invention, a sorbent for sulfur emissions may be injected before the device to capture sulfur dioxide emissions prior to the filter elements and the catalyst. In this manner, the sulfur dioxide may be captured prior to the gases contacting the catalyst, preventing the potential formation of sulfur trioxide within the filter elements through catalytic oxidation.

In one variation of the invention, a sorbent for capture of mercury emissions is injected after the filter device in order to capture mercury emissions which have been oxidized in contact with the catalyst.

In one variation of the invention, a nitrogenated agent such as ammonia, urea, ammonium bisulfate, or flyash may be injected prior to the filter device in order to reduce NO_X emissions. For example, injection of ammonia may be placed immediately prior to the inlet of the filter device, or may be injected in excess within the industrial process producing the exhaust gas with the resulting ammonia slip further reacting within the filter device.

Placement of the catalytic filter device into the industrial process is dependent upon the pollutants in the exhaust gas stream that are to be destroyed. The activity of the catalyst and the selectivity of the catalyst for destruction of gaseous emissions are dependent upon the temperature of the gas stream. Organic compounds such as methanol can be destroyed in large percentages even at temperatures as low as 120°C, while organic compounds such as propane may require temperatures as high as 300°C. It is preferential for the destruction or reaction of shorter-chain (less than 7 carbon atoms) hydrocarbons, of single-bonded (i.e. saturated) hydrocarbons, and NO_X emissions to place the device as close to the exhaust of the cement or minerals processing system as is possible in order to obtain a gas temperature in the range of 250 to 400 °C, and more preferentially 300 to 350 °C. If the destruction or reaction of longer-chain hydrocarbons (7 or more carbon atoms), double- or triple-bonded (i.e. unsaturated) hydrocarbons, and/or cyclic or aromatic hydrocarbon compounds are desired, without need for higher temperatures for the treatment of other emissions through catalytic means, then the device may preferentially be used in the temperature range of 80 °C to 250 °C, and more preferentially between 150 °C and 200 °C.

The catalytic activity of the filter elements may also be enhanced through the treatment of the gas stream with other means. These means would include the use of ozone, peroxide, potassium permanganate, calcium chloride, sodium hydroxide, or other oxidizing species injected upstream of the filter element or within the filter device.

The invention is explained in greater detail below with the aid of drawings.

In the system of the present invention illustrated in FIG. 1, material is treated in a kiln **1**, which heats the material to undergo chemical changes. In cement kiln systems, the feed entering kiln **1** through conduit **2** may first be preheated in a preheater system **50** comprising a number of counter current heat exchangers **51** in the form of cyclones. The material may also pass through a calciner or pre-calciner **52** for removal of carbon dioxide prior to entering kiln **1**. Product from kiln **1** is discharged into a material cooler **3** which serves the purpose of cooling the kiln product before discharge **4**, and of recuperating heat from the product to be returned to the kiln **1** or to the calciner **52**. Cooling air is passed over the material and is heated before passing through the kiln hood **5** to enter kiln **1** or to enter the calciner **52** through conduit **6**. The air flowing to kiln **1** and calciner **52** is utilized in combustion process. Excess air that enters cooler **3** for product cooling is directed to an exhaust vent **7**. In typical arrangements, the air exiting cooler **3** through exhaust vent 7 are cooled in a heat exchanger **8**, and entrained particulate matter is removed in a dust collector **9** and removed as a product stream **10**. The cooler excess air may then be vented to atmosphere at **11**, or used in other means within the process. Gases exiting from kiln **1** are directed through calciner **52** and into preheater system **50**. Feed material **20** to the system is directed to the preheater system **50** for thermal treatment, and may be split between various counter current heat exchangers **51** for the control of temperature from the exhaust gas **21** or for the high temperature treatment of the feed material. In the typical configuration, the feed material is directed to the uppermost cyclone heat exchanger as depicted. Emissions of organic compounds, mercury, and carbon monoxide from the thermal treatment of feed material **20** within preheater system **50**, and emissions of organic compounds, carbon monoxide, and other products of incomplete combustion from the calciner **52** or kiln **1**, will leave the system in the exhaust gas stream **21**. Nitrogen oxides created and mercury released from combustion processes in calciner **52** and kiln **1** will also leave the system in the exhaust gas stream **21**. The exhaust gas from the kiln system is then directed through the catalytic filter system **100** for the destruction or reaction of gaseous emissions in exhaust gas stream **21**. After passing through the catalytic filter system **100**, treated exhaust gas stream **22** may be directed to a gas conditioning tower **23** which utilizes cooling water **24** for the cooling of the gas stream for further processing. Conditioned gas **25** from the gas conditioning tower **23** may be directed to a raw mill system **60** or multiple mill systems, or to a main dust collector **70** for final particulate control. Raw feed materials **61** are introduced to the raw mill system **60** which grinds the feed materials to a size suitable for the production of cement clinker. The product material from the mill exits the mill **60** with an exhaust gas stream **65** and is separated in a collection device such as a cyclone **62** or cyclones. The material **63** captured in the cyclone **62** is transported to a blending and/or storage silo **90** for use in the kiln system. The gases **64** from cyclone **62** are then directed to a main dust collector **70** for collection of fine particulate matter not captured in the cyclone. The gases from the main dust collector may then be vented from the system **80**. Material **71** captured in the main dust collector is then transported to the blending and/or storage silo **90**, or to some other storage area for further treatment or disposal. Material blended and/or stored in silo **90** is used as kiln feed **20** for the kiln system. If the kiln system utilizes a solid fuel for heating of material, hot gases may be removed from the system **31** for use in a milling system for the solid fuel or for other heating processes within the plant facility. The hot gases may alternatively be removed from the system after the catalytic filter system and before the gas conditioning tower, or after the gas conditioning tower and before the main dust collector. Exhaust gases from the solid fuel grinding system may be returned to the system in a gas stream **41** prior to the catalytic filter system, may be directly vented to atmosphere, or may be combined with the exhaust gases **80** from the main dust collector **70** before being vented to the atmosphere.

The catalytic filter system **100** is depicted as being positioned between the preheater/precalciner system and the gas conditioning tower, but depending on the configuration of the kiln system and the requirements for gas flows for processing within the system, the catalytic filter system may alternatively be placed at a number of other locations within the system. For example, the catalytic filter system may be placed at location **A** (between the exit of the preheater system **50** and the hot gas stream **31** removed from the preheater exhaust gas stream **21**), at location **B** (between the hot gas stream **31** removed from preheater exhaust gas stream and the returned gas stream **41** from the solid fuel grinding system), or at location **C** (after the exhaust of the gas conditioning tower **23**).

It may be preferred to utilize sorbents in the process prior to the position of the catalytic filter system in order to capture items that otherwise may oxidize to less preferable components in the catalytic filter systems. Sorbents such as calcium oxide, calcium hydroxide or hydrated lime, trona, activated carbon, or proprietary sorbents such as Minsorb^{TM} or Sorbacal^{TM}, may be utilized in this capacity in one or all of locations **S1**, **S2**, and **S3**. The injection of additional reactive agents such as ozone, peroxide, potassium permanganate, calcium chloride, sodium hydroxide, or other oxidizing species, or ammonia, urea, or other nitrogenous compounds for conversion of emission components to those more readily destroyed within the catalytic filter system or to directly improve the destruction of compounds in the catalytic filter system may be utilized in one or all of locations **S1**, **S2**, **S3**, **S4** and **S5**.

FIG.2A shows one embodiment of the present invention, with emphasis on area 100 of FIG. 1. Process gases **101** from the exit of the kiln installation, such as the exit of a cement kiln, preheater, or precalciner system or a lime kiln or preheater system are directed via a conduit **102** to the catalytic filter unit **103**. Filter unit 103 comprises housing XXX, which encloses an interior portion of the unit which is partitioned by a sheet **105** through which filter elements **104** are inserted. The filter elements are a porous material, such as a fiberglass bag or a porous ceramic structure, which will allow the process gases to pass through, but which will trap a large portion of particulate matter on the surface of the filter element. It is preferred that the porous filter will reduce the dust load of the gas passing through the filter element to 5 grams per cubic meter of process gas or less, preferentially less than 30 milligrams per cubic meter of process gas, and most preferentially less than 5 milligrams of particulate per cubic meter of process gas. Particulate matter collected on the surface of the filter elements is removed from the surface of the filter and collected in the bottom of the device at **106** and removed through a withdrawal system **107**. Cleaning of the material on the surface may be conducted on a routine basis at set time intervals, or may be controlled by monitoring the accumulation of material on the filter element surface by means of a pressure monitoring device **108** to monitor the difference in pressures attained across the partition between the clean and dirty sides of the filter. Gases passing through the filter elements come into contact with the catalytic material with which the filter elements have been treated or produced. Contaminants such as organic compounds react upon the catalytic elements of the filter elements and are destroyed. The reaction activity of the catalyst to increase the reduction of hydrocarbons present in the filtering element may be improved by contacting the catalytic agents with a reactive agent, such as by injecting one or more reactive agents at a point located prior to the catalytic filter as described previously. The temperature of the gas stream is monitored at position **109** to ensure that the interior of the filter device is maintained at a temperature that facilitates sufficient activity of the catalyst, and if the temperature within the filter device is not suitable for the destruction of the targeted pollutant(s), process changes can be made prior to the catalytic filter to ensure sufficient temperature for efficient destruction of the entrained pollutants. The temperature within the filter device can also be controlled through the introduction of a gas stream **120** prior to the catalytic filter system. Examples of gas streams for temperature control include ambient air introduced by a fan or damper to reduce inlet temperature, hot gas streams from heat sources such as stand-by heaters, or waste heat from other areas of the cement or minerals processing kiln system such as from a cooler vent exhaust stream. While depicted as being located on the clean side of the filter elements at 109, the temperature monitor can be placed on the dirty side of the filter, or in the duct work prior to or after the catalytic filter.

The cleaned gases **110** exit the catalytic filter via a duct **111**, and can be used elsewhere in the process or vented to atmosphere.

FIG. 2B shows a more detailed view of a filter element **104**. The gas stream with entrained particulate matter **152** impacts on the surface of the filter element adjacent to the filter elements **156**. The gas stream follows the direction of flow as shown by dotted line **151** and is forced through the porous portion **150** of the filter element to come into contact with catalytic agents container therein. The clean gas stream from which particulate matter has been removed passes to the "clean side" **155** of the filter. The particulate matter **154** entrained in the gas stream is collected on the surface of the dirty side of filter elements **104** and is removed periodically.

While the filter elements are depicted in FIG.2A as being supported by the partition within the catalytic filter, and the inlet gas enters below the partition and exits above the partition, multiple arrangements of partition, filter elements, and gas inlets and outlets may be utilized depending on the possible layouts within the system and the materials of construction used for the catalytic filter and the filter elements. By example, a porous ceramic filter element may be limited in length by the strength of the filter element at the support point, which may necessitate a large number of filter elements to achieve sufficient particulate matter control or catalytic activity. In this example, it may be necessary to utilize a filter element which is supported from beneath by the partition to allow for a greater strength in compression than is available in tension.

FIG. 3 depicts another embodiment of the system and method of the present invention in the context of a cement or minerals processing kiln installation. Process gases **201** from the exit of the kiln installation, such as the exit of a cement kiln, preheater, or precalciner system or a lime kiln or preheater system are directed via a conduit **202** to the catalytic filter unit **203**. The filter unit is partitioned by sheet **215** and sheet **216** through which filter elements **204** are inserted. The support provided to filter element **204** by sheet **215** is in tension, while the support provided to filter element **204** by sheet **216** is in compression. With, for example, a ceramic filter, as element **204** gets longer its weight becomes a concern at the support point. If such an element is supported only from above a large shear stress can be created on the element and it can crack at the support. It it's also supported from below, the stress is in compression, which is easier for the ceramic to accommodate without cracking. By distributing the support for the element in this manner, a longer filter element may be used in the filter device. By using a longer filter element, fewer elements may be used in the filter device. The longer elements will increase the height of the filter device, but this can save on the length and width of the filter device, which may be of critical importance when installing the filter device in areas with other existing equipment.

Particulate matter collected on the surface of the filter elements is removed from the surface of the filter and collected in the device **206** and removed through a withdrawal system **207**. Pressure monitoring device **208** is used to monitor the difference in pressures attained across the partition between the clean and dirty sides of the filter. The temperature of the gas stream is monitored at **209** The cleaned gases **210** exit the catalytic filter via a duct **211**.

FIG. 4A depicts another embodiment of the system and method of the present invention. Process gases **301** from the exit of the kiln installation are directed via a conduit **302** to the catalytic filter unit **303**. The filter unit features a number of filter elements **304** supported on a series of chambers or plenums **317** through which air passes from the interior of the filter elements to the exterior of the filter device via exit **311**. Each plenum **317** supports a plurality of filter elements, an arrangement shown more clearly in Fig. **4B**, and plenums **317** are closed from the inlet stream with a partition **316**. The filter elements are supported from lateral movement with a support structure **315**. The support provided to the element by partition **316** is in compression. Particulate matter collected on the surface of the filter elements is removed from the surface of the filter, falls between the clean air plenums at **319**, and is collected in the device **306** and removed at **307**. The arrangement allows for a flow of gas to exit at **311** from the bottom of the filter, that is, below the elements. This allows for the installation of this filter in line with the existing gas flow from the exhaust duct of some types of kiln systems using cyclone preheaters, and is an advantage in retrofit applications. By employing the arrangement of FIG. 4A and 4B, the ID fan can be closer to the tower, and the support of the elements is such that a longer element could be used. Overall, this would allow for the tallest and skinniest installation, allowing for the easiest retrofit in many installations. Pressure monitoring device **308** monitors the difference in pressures attained across the partition between the clean and dirty sides of the filter. The temperature of the gas stream is monitored at **309** The cleaned gases **311** in the chambers or plenums are removed from the catalytic filter via a duct **310**.

FIG. 4B depicts an isometric view of the embodiment depicted in Figure 4A, with similar numbers depicting similar elements. Process gases **301** from the exit of the kiln installation, such as the exit of a cement kiln, preheater, or precalciner system or a lime kiln or preheater system are directed via a conduit **302** to the catalytic filter unit **303**. The filter unit features a number of filter elements **304** supported on a series of chambers or plenums closed from the inlet stream with a partition **316**. The filter elements are supported from lateral movement with a support structure **315**. Particulate matter collected on the surface of the filter elements is removed at **307**. The cleaned gases **311** in the chambers or plenums are removed from the catalytic filter via a duct **310**.

FIG. 5 shows a similar system as depicted in FIG. 1, but utilizes the catalytic filter system **100** in place of the main dust collector **80** shown in FIG. 1. In FIG.5, similar numbers to those of FIG. 1 depict similar elements. This arrangement offers the advantage that the use of pollution control equipment is minimized, as the catalytic filter system is used as the main dust collector, which in turn reduces the installation and operational costs as well as power consumption. The use of this arrangement is more difficult to implement in that the operating temperatures of the incoming gas stream are typically lower than the operating temperatures found nearer to the exit of the kiln or preheater system. This arrangement is preferred when the primary emissions that the catalytic filter system is intended to destroy can be effectively reduced in the temperature range found in this location. As an alternative, a hot gas source **95**, such as a portion or all of the gas stream leaving the cooler vent and removed from gas stream **7**, between heat exchanger **8** and dust collector **9**, or from the stack gas **11**, may be used to return the gas temperature to a higher range which will improve the activity of the catalytic filter system. The use of waste heat from the cooler vent system is preferred in that dust collector **9** may also be eliminated in whole or reduced in size if sufficient gas flow is continuously removed from this location, further reducing installation and operational costs as well as system power consumption.

FIG. 6 shows an example set of organic compound reduction curves comparing the removal efficiency of a catalytic filter system operated at varying temperatures for different examples of organic compounds for a catalytic filter system of the invention. The catalyst in use exhibits greater than 90% destruction of methanol at temperatures ranging between 100 and 225 °C, increasing rates of toluene removal from less than 30% at approximately 120 °C to greater than 90% destruction above approximately 200 °C, increasing rates of heptanes destruction ranging from less than 50% at approximately 160 °C to greater than 90% above approximately 240 °C, and increasing propane removal from 20% at 300 °C to greater than 60% at approximately 370 °C. In laboratory testing, generation of these hydrocarbon reduction curves is achieved through the passage of a carrier gas of similar composition to the gas stream exiting a cement or minerals processing system containing carbon dioxide, water vapor, nitrogen, and oxygen, as well as typical particulate matter in set concentrations, and introducing known quantities of hydrocarbons into the gas stream. Measurements taken before and after the catalytic filter system are used to determine the percentage of incoming organic compound that is destroyed within the catalytic filter system. Varying the temperature of the gas stream in the catalytic filter system provides data for the generation of the reduction curve with regard to temperature. Organic compound reduction curves such as that depicted in FIG.6 will vary with the selection of the catalytic elements used in the production of the filter elements utilized in the catalytic filter system, as well as any reactive agents utilized in conjunction with the catalytic filter elements. Knowledge of the constituent organic compounds in the cement or minerals kiln or calciner exhaust gas, through direct measurement or previously established predictive means, in comparison to organic compound reduction curve with regard to operating temperature, can be utilized to select the location and specific design configuration of the catalytic filter system as depicted in FIGS. 1 through 5, or in similar variations. As an example, the control of a process gas stream containing high levels of methanol and toluene may more efficiently utilize the catalytic filter system as depicted in FIG. 5 and FIG. 6, while the control of a process gas stream containing high levels of propane may more efficiently utilize the catalytic filter system as depicted in FIG. 1 and FIG. 6.

Using this invention, the exhaust gases from an industrial plant such as a cement or mineral kiln can be treated to reduce or destroy organic compounds and other pollutants from the exhaust until the total content of organic compounds and other pollutants in the gas stream is below levels that may be considered safe for release to the atmosphere. Treatment of the gas stream may also allow for removal of other pollutants, or additional treatment downstream.

The invention having been thus described it will be obvious that the same may be varied in many ways without departing from the spirit and scope thereof. All such modifications are intended to be included within the scope of the invention which is defined by the following claims.

We claim:

1. A method for the reduction of contaminant emissions including organic compounds present in vapor form from the process gases of an industrial plant utilizing a kiln and/or calciner to heat treat a raw material, said method comprising
   (i) directing plant process gas containing entrained particulate matter and contaminant emissions from the plant to a pollution control device comprising a process gas inlet and process gas outlet and an interior portion located intermediate the inlet and outlet, said interior portion containing at least one filtering element for removing the particulate matter from the gas, said at least one filtering element containing at least one catalyst for removing some of the contaminant emissions;
   (ii) directing the process gas through the inlet and thereafter through the filtering element, wherein entrained particulate matter is separated from the process gas and the process gas comes in contact with the at least one catalyst to thereby reduce the contaminant emissions contained in the gas ; and
   ;
   (iii)directing cleaned process gas through the outlet of the pollution control device.
2. The method of claim **1** further comprising:
   removing the separated particulate matter from the pollution control device.
3. The method of claim **1** wherein the process gas is comprised of at least one of kiln off gas, preheater off gas, precalciner off gas, raw material milling system off gas, solid fuel milling system off gas product cooler vent gases and kiln process product milling off gases.
4. The method of claim 3 wherein the process gases comprise product cooler vent gases.

5. The method of claim **1** wherein the process gases within the pollution control device are maintained at a temperature between 80° C and 450° C.

6. The method of claim **1** wherein the at least one catalyst is selected from the group comprising vanadium, platinum, palladium, ruthenium, titanium, lanthanum, cerium, yttrium, zirconium, tungsten, manganese, niobium, molybdenum, nickel, iron and copper.

7. The method of claim **1** wherein the filtering element is a fiberglass bag.

8. The method of claim **1** wherein the filtering element is treated with a membrane.

9. The method of claim **1** wherein the filtering element is a porous ceramic structure.

10. The method of claim **1** wherein at least one reactive agent is contacted with the at least one catalyst agents to increase the reduction of hydrocarbons present in the filtering elements.

11. The method of claim **10** in which the at least one reactive agent is selected from the group comprising ozone, peroxide, potassium permanganate, calcium chloride, sodium hydroxide, sodium bromide, bromine and chlorine.

12. The method of claim **2** wherein removal of the separated particulate matter from the pollution control device is achieved by pulsing gas through the filtering elements.

13. The method of claim **2** wherein removal of the separated particulate matter from the surface of the filtering elements is achieved through sonic or ultrasonic vibration.

14. The method of claim **2** wherein removal of the separated particulate matter from the surface of the filtering elements is achieved through mechanical removal of particulate matter with a solid object.

15. The method of claim **2** further comprising:
returning the removed particulate matter to the industrial plant process.

16. The method of claim **1** in which the organic compounds comprise Total Hydrocarbons.

17. The method of claim **1** wherein the organic compounds comprise at least one of formaldehyde, acetaldehyde, xylene, benzene, styrene, and naphthalene.

18. The method of claim **1** wherein the organic compound comprise Volatile Organic Compounds.

19. The method of claim **1** in which mercury compounds within the process gas are oxidized by the at least one catalyst.

20. The method of claim **1** wherein at one of nitrogen oxides, dioxin/furan emissions and carbon monoxide are reduced by the at least one catalyst.

21. The method of claim **1** further comprising injection of a sorbent upstream of the pollution control device for the adsorption of at least one of sulfur dioxide, sulfur trioxide, arsenic, thallium, mercury, hydrogen chloride, hydrogen fluoride, or hydrogen bromide.

22. The method of claim **21** wherein the sorbent includes at least one of calcium oxide, calcium hydroxide, trona, sodium bicarbonate, cement kiln dust, calcined material, and activated carbon.

23. The method of claim **19** wherein a nitrogenated agent is introduced to increase the reduction of nitrogen oxides.

24. The method of claim **23** wherein the nitrogenated agent includes at least one of ammonia, urea, ammonium bisulfate, or flyash.

25. The method of claim **1** further comprising injection of a sorbent downstream of the pollution control device for the adsorption of at least one of sulfur dioxide, sulfur trioxide, arsenic, thallium, mercury, hydrogen chloride, hydrogen fluoride, or hydrogen bromide.

26. The method of claim **25** wherein the sorbent includes at least one of calcium oxide, calcium hydroxide, trona, sodium bicarbonate, cement kiln dust, calcined material, and activated carbon.

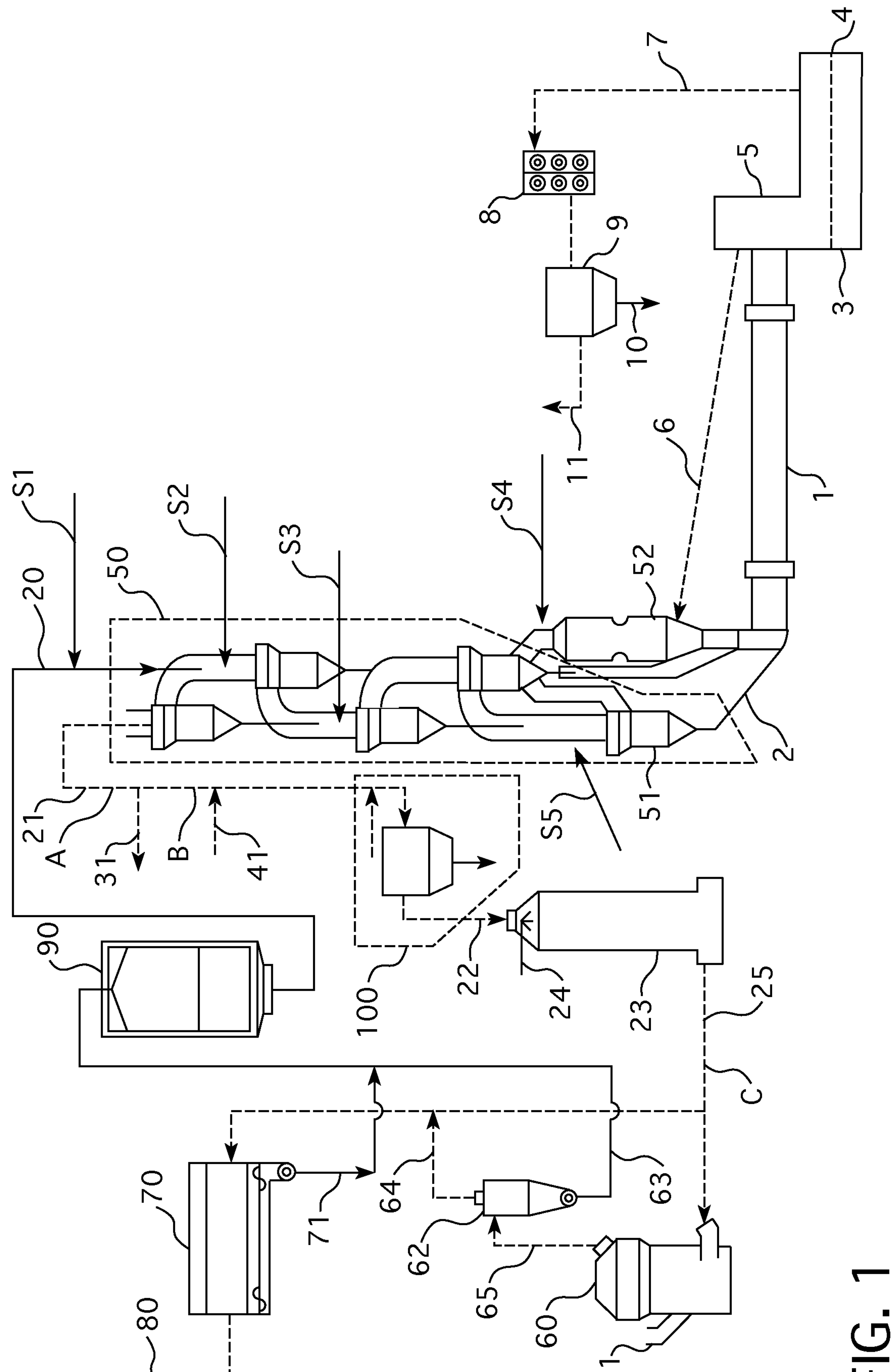
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FIG. 1

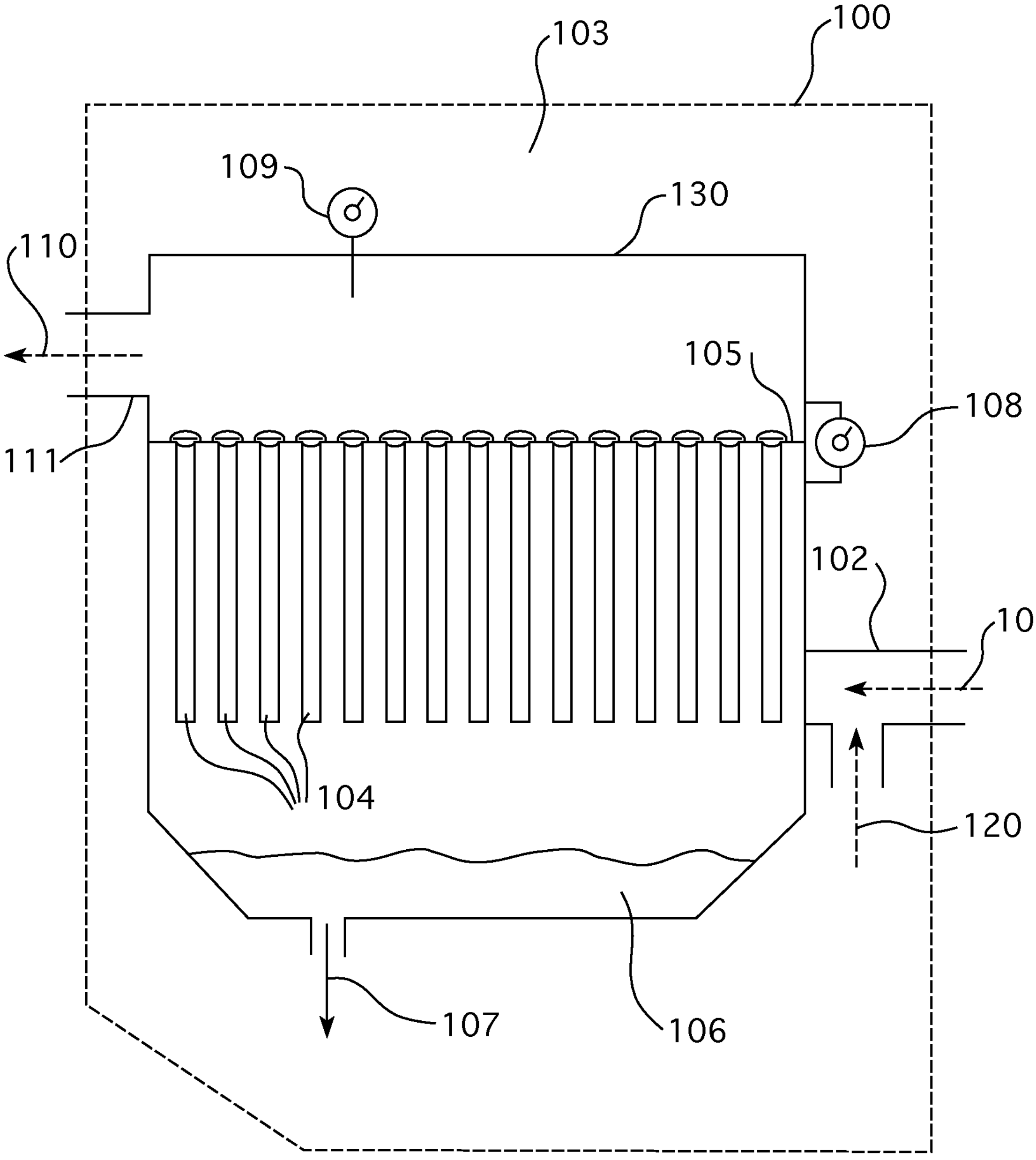


FIG. 2A

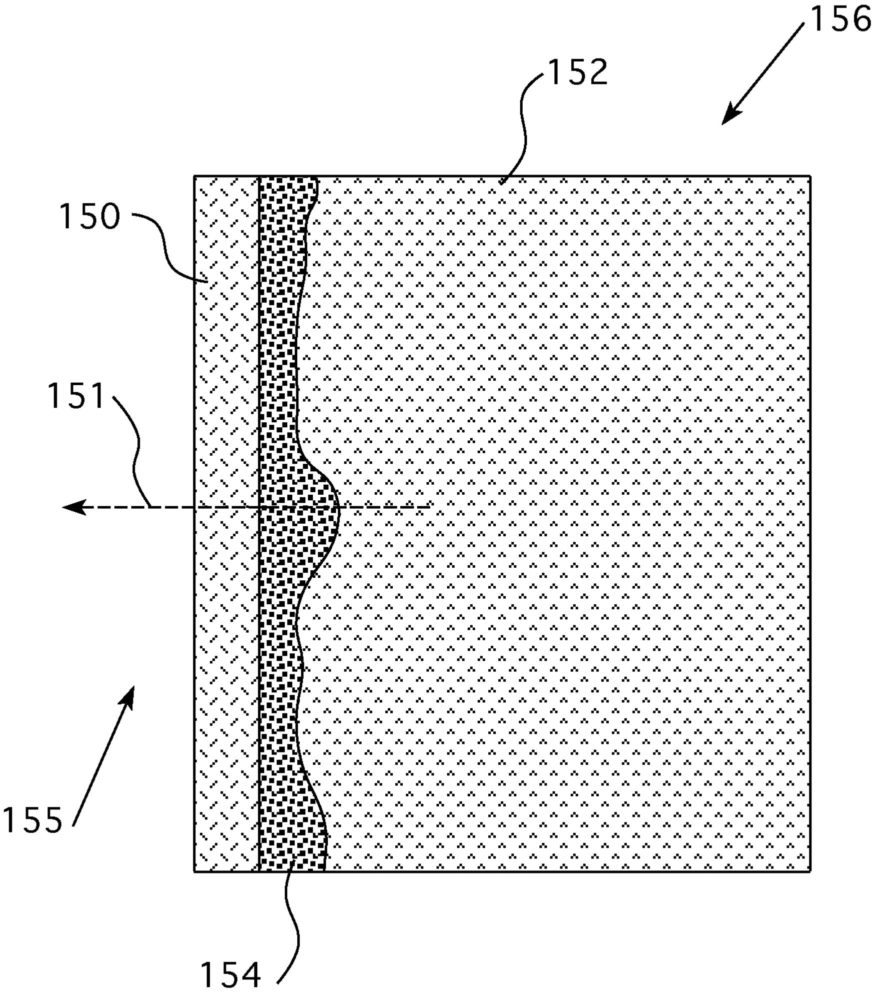


FIG. 2B

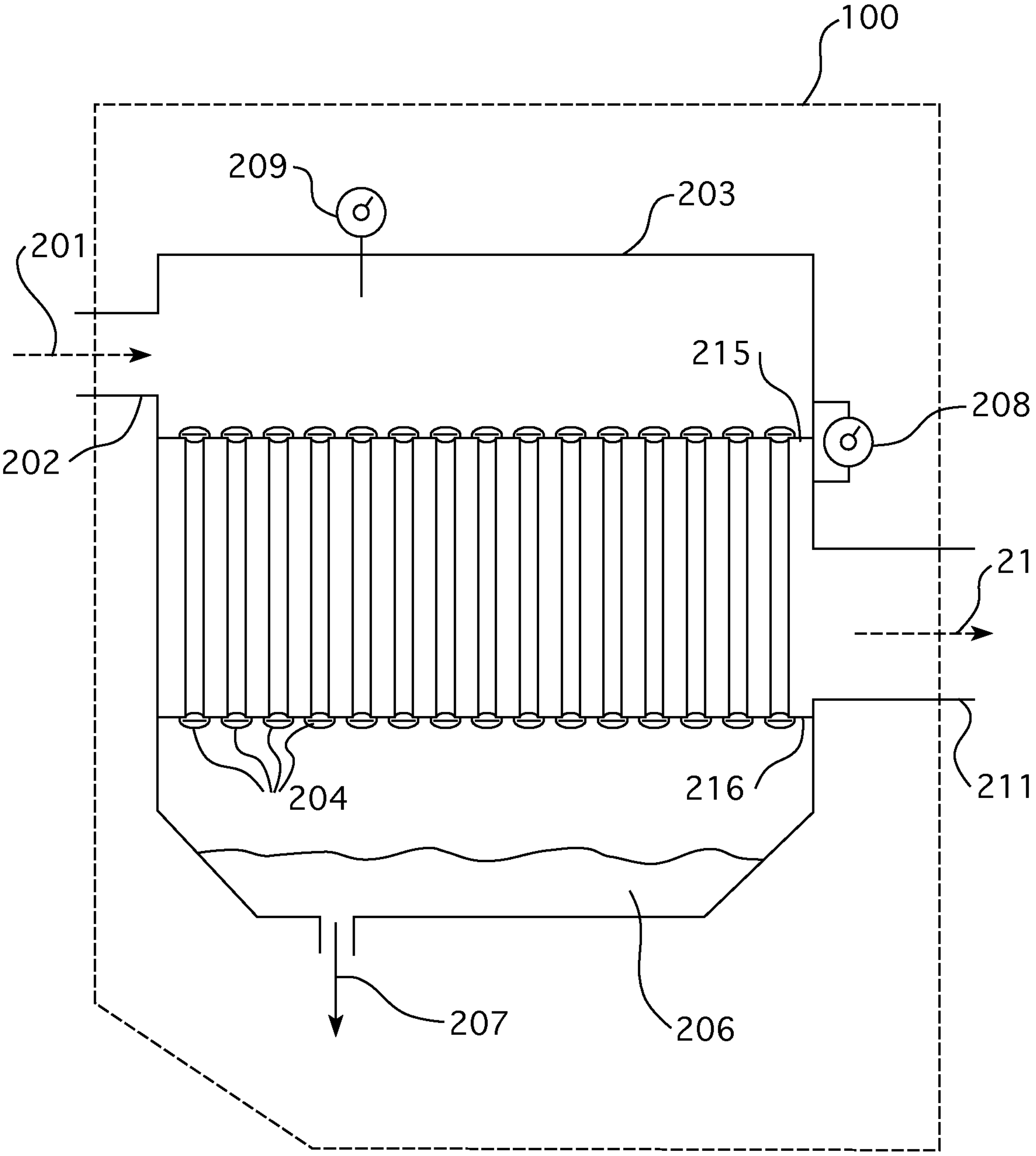


FIG. 3

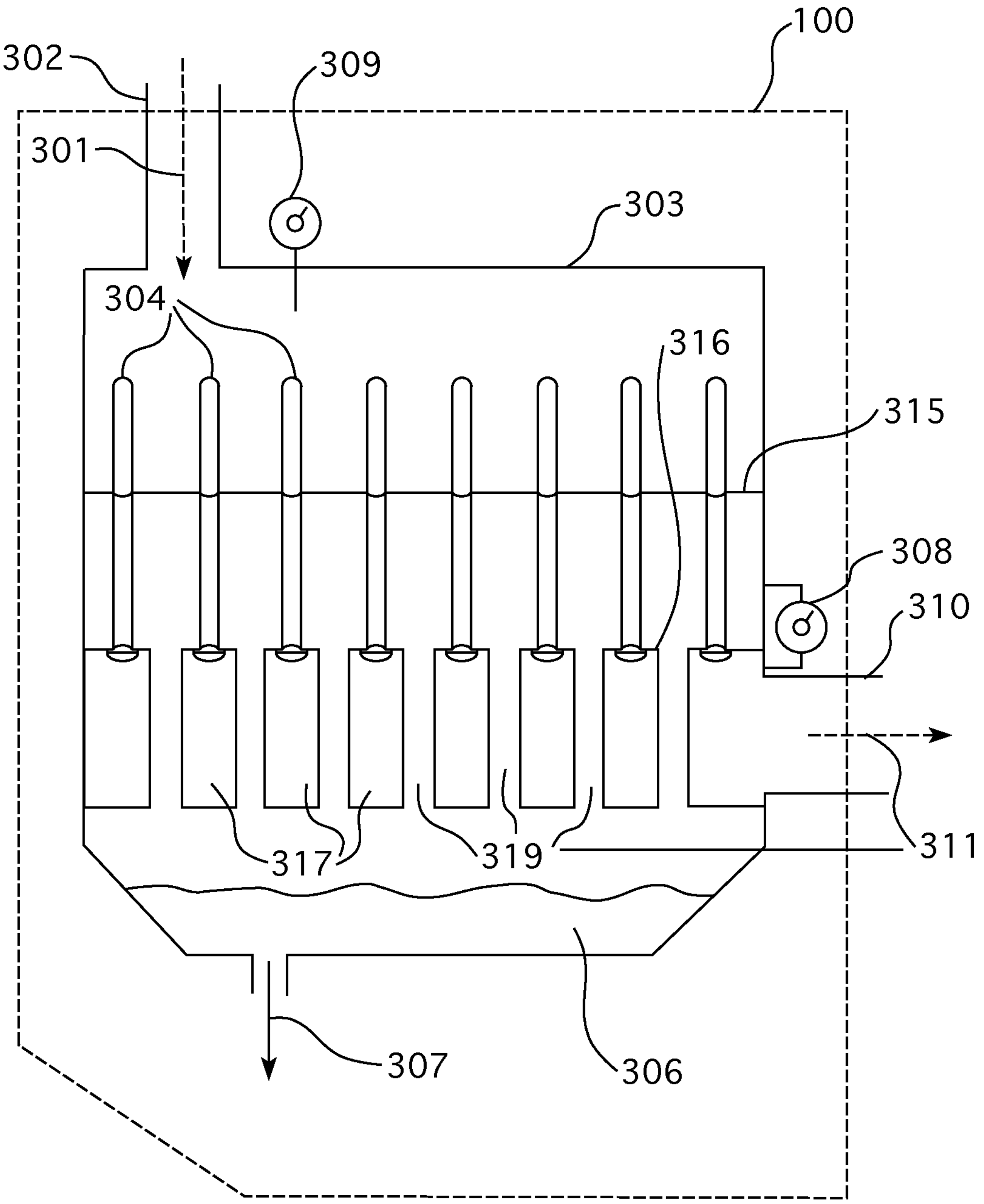


FIG. 4A

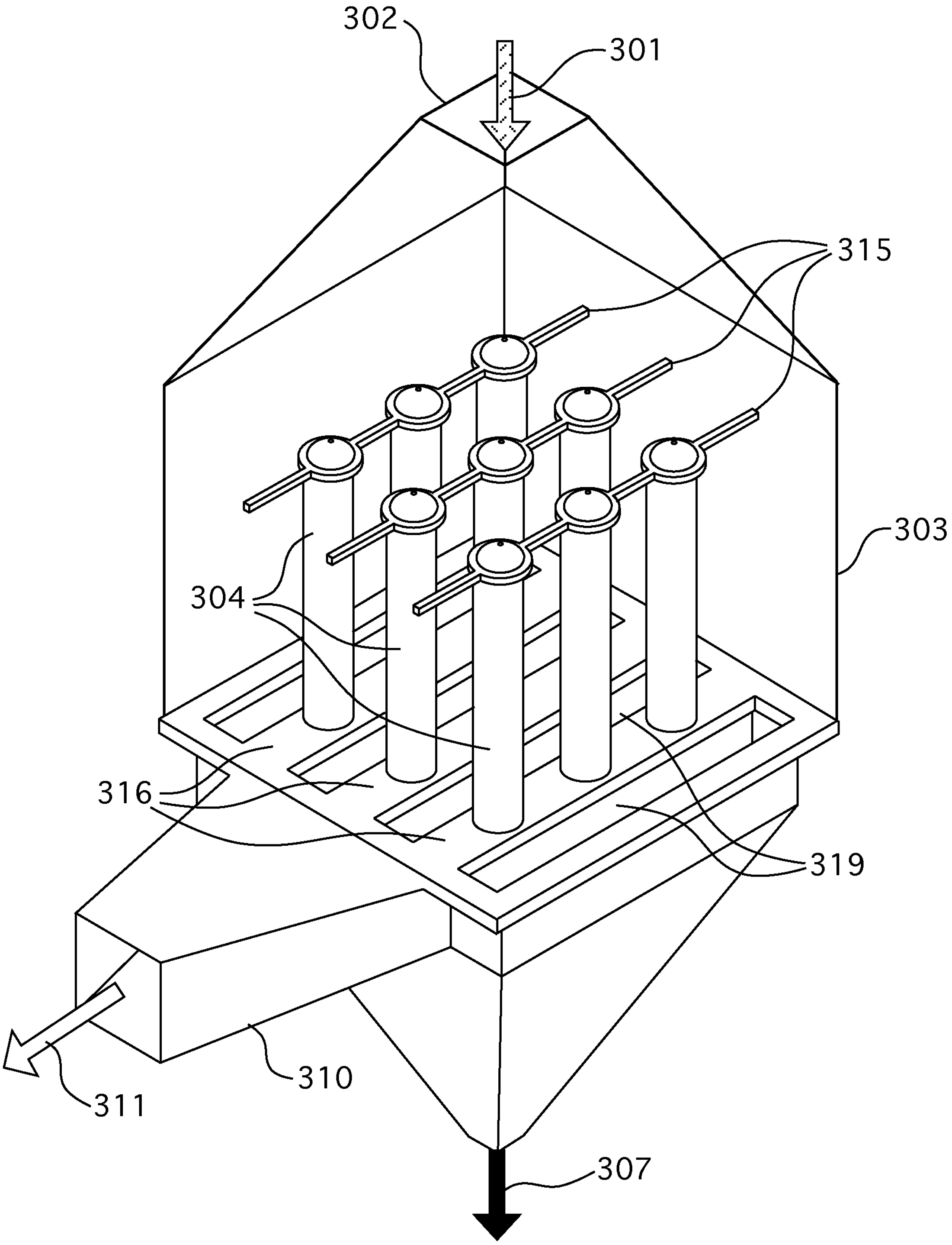
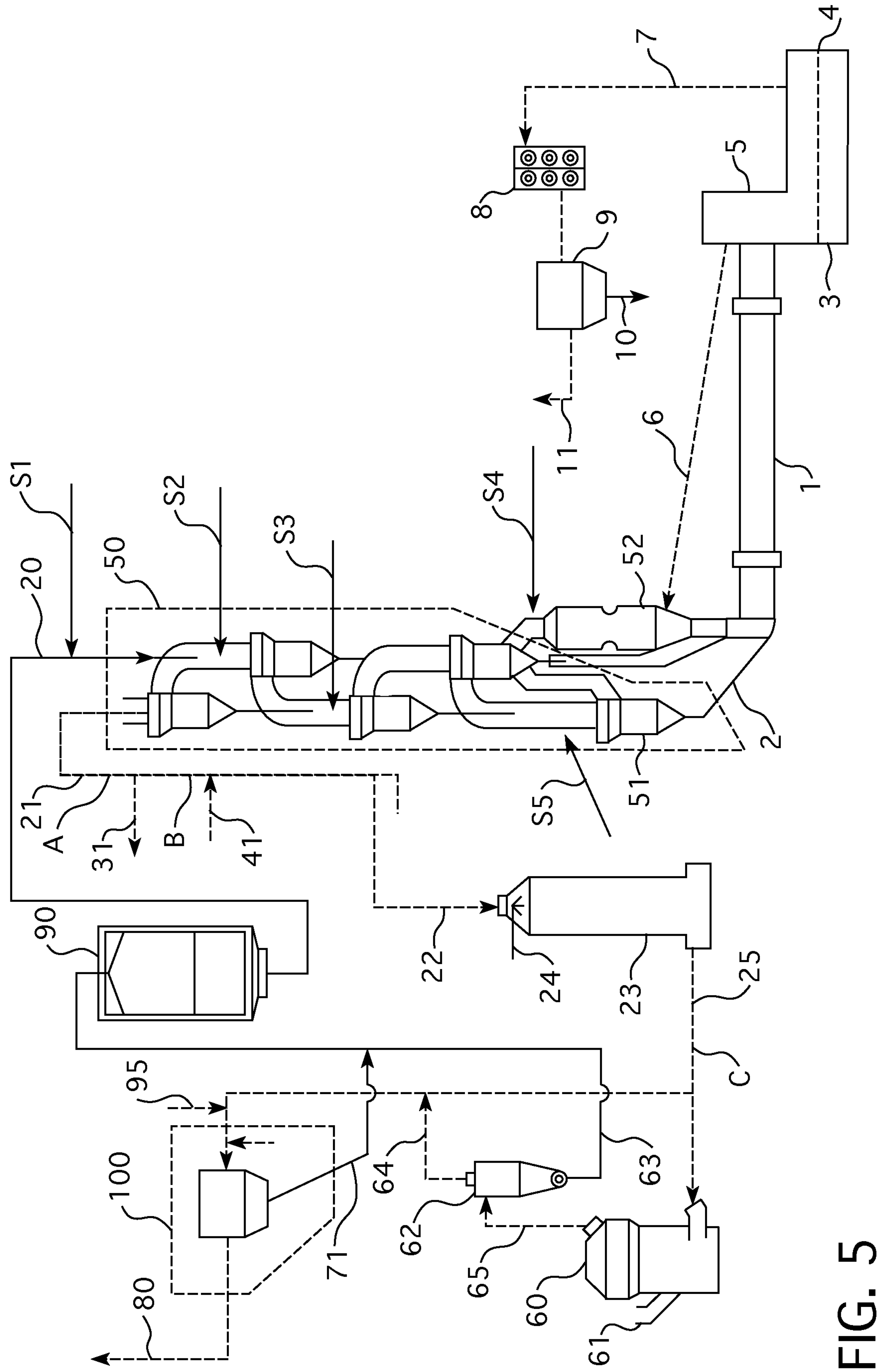


FIG. 4B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A
31
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25
C
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FIG. 5

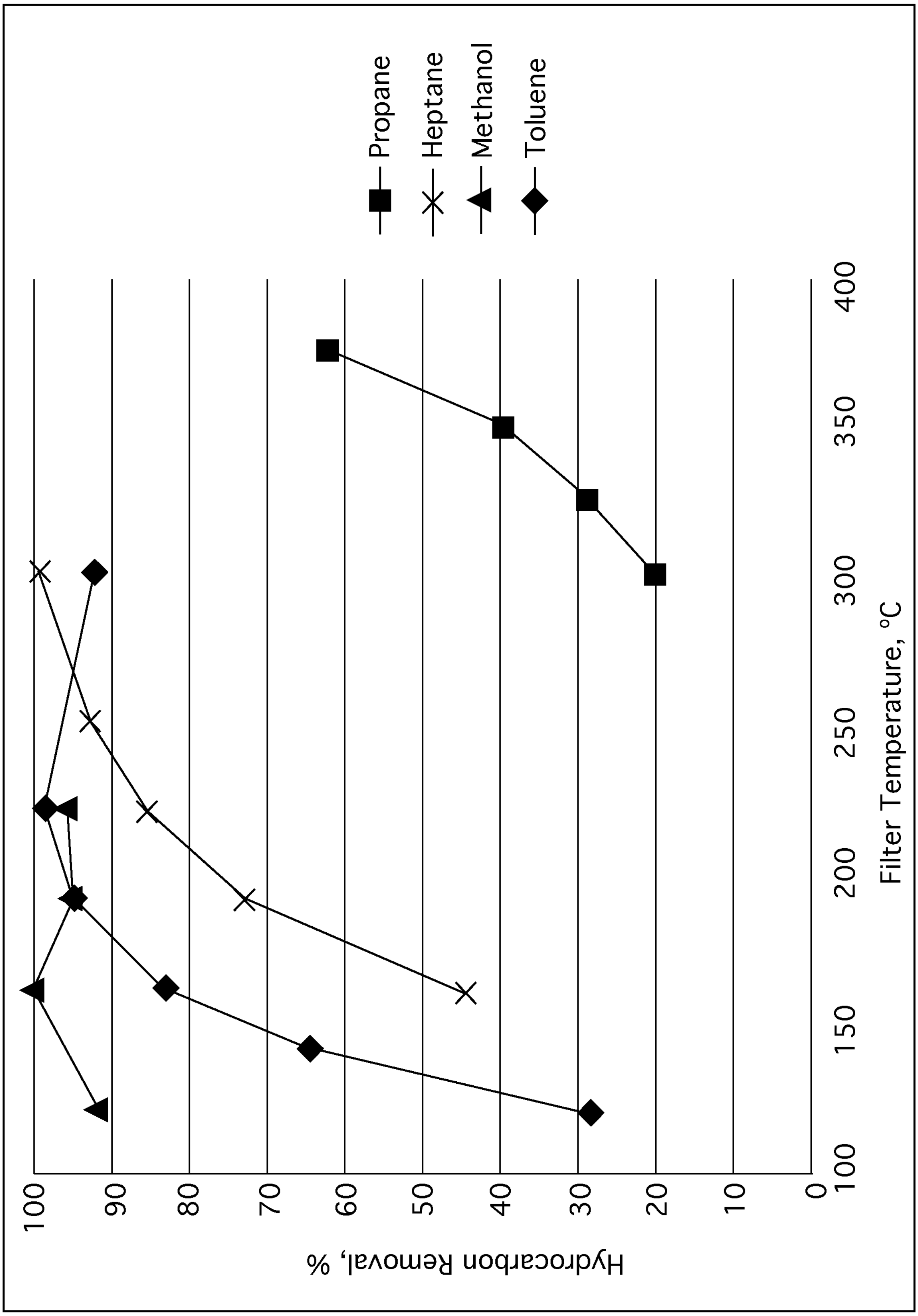
Hydrocarbon Removal, %
100
90
80
70
60
50
40
30
20
10
0
100
150
200
250
300
350
400
Filter Temperature, °C
Propane
Heptane
Methanol
Toluene

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/46848

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F23J 15/00 (2012.01); B01D 53/34 (2012.01)
USPC - 110/203; 422/168
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: F23J 15/00 (2012.01); B01D 53/34 (2012.01)
USPC: 110/203; 422/168

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC: F23J 15/00 (2012.01); B01D 53/34;
USPC: 110/203, 216, 217; 422/168, 169, 176, 177, 178, 616, 651; 423/210, 212, 213.2

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest, Google Scholar: Keywords: emission, gases, kiln, calciner, cement, filter, catalyst, preventing, particulate, clogging, blocking, choking, plugging, industrial, --Continued on Supplemental Box--

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	WO 98/03249 A1 (BOSCAK) 29 January 1998 (29.01.1998), entire document, especially; FIG 3, pp 1, 5, 6, 7, 9-14.	1-3, 5-9, 12, and 19-26 --- 4, 10, 11, 13-18
Y	US 2010/0307388 A1 (SECKLEHNER) 09 December 2010 (09.12.2010), entire document, especially; Fig. 1, para [0001], [0019], [0025]-[0029], [0043], [0046], [0048]-[0049], [0060], claims 9-10.	16, 18
Y	US 5,318,755 A (KUIVALAINEN et al.) 07 June 1994 (07.06.1994), entire document, especially; Figs. 1-7, col 1, ln 5-10, col 4, ln 58-65, col 7, ln 5-65, col 8, ln 3-25.	4, 13-15
Y	US 5,670,122 A (ZAMANSKY et al.) 23 September 1997 (23.09.1997), entire document, especially; col 5, ln 23-56, col 8, ln 9-20.	10-11
Y	US 2009/0169453 A1 (SAITO et al.) 02 July 2009 (02.07.2009), entire document, especially; Para [0021], [0042]-[0044].	17
A	US 7,618,603 B2 (SEAMES et al.) 17 November 2009 (17.11.2009). Col 1, ln 10-15, col 2, ln 50-65, col 3, ln 12-14, claim 3, 6-9.	1-26
A	US 6,863,868 B1 (ALVIN) 08 March 2005 (08.03.2005). Fig. 1-6; col 1, ln 5-40, col, 3, ln 45-62, col 7, ln 2-3, col 7, ln 3-5, col 7, ln 52 to col 8, ln 68, col 9, ln 28-67, col 10, ln 1-10.	1-26
T	ECAT, "Metal Catalyst for VOC Oxidation" 3rd para. [Retrieved from Internet 16 September 2012]. <URL: http://www.ecocatalysis.com/en/articles/VOC.html>.	1-26

☒ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
14 September 2012 (14.09.2012)

Date of mailing of the international search report
15 OCT 2012

Name and mailing address of the ISA/US
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Facsimile No. 571-273-3201

Authorized officer:
Lee W. Young
PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/46848

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP2009298677 A (JUNICHI et al.) 24 December 2009 (24.12.2009), entire document.	1-26
A	US 5,620,669 A (PLINKE et al.) 15 April 1997 (15.04.1997). Figs. 6-10, col 5, ln 15-30, col 6, ln 15-33 and 48-49, col 8, ln 8-65.	1-26
A	US 2010/219373 A1 (SEEKER et al.) 02 September 2010 (02.09.2010). Para [0002], [0106].	1-26

continued...

B. FIELDS SEARCHED
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

plant, process, particles, dust, pollution, cleaning, sweeping, shaking, dropping, vibration, pulsing, backflushing, purging, preheater, precalciner, raw material milling, solid fuel milling, kiln product milling, off gas, cooler vent gas, organic compound, cooling gas, lime, product, calcium oxide, catalyst, vanadium, platinum, palladium, ruthenium, titanium, lanthanum, cerium, yttrium, zirconium, tungsten, manganese, niobium, molybdenum, nickel, iron, copper, fiberglass bag, membrane filter, porous ceramic, reactive agent, ozone, peroxide, potassium permanganate, calcium chloride, sodium hydroxide, sodium, bromide, bromine, chlorine, Volatile Organic Compounds, VOC, Total Hydrocarbons, THC, Total Organic Carbon, TOC, sorbent, absorption, absorbing, sulfur dioxide, sulfur trioxide, arsenic, thallium, mercury, hydrogen chloride, hydrogen fluoride, hydrogen bromide, Minsorb, Sorbacal, calcium oxide, calcium hydroxide, trona, sodium bicarbonate, cement kiln dust, calcined material, activated carbon, FLSMIDTH, SCHMIDT-Iver, RASMUSSEN-Jorn, PAONE$-Peter, SALMENTO-John, DEJOSEPH-Daniel, sonic, ultrasonic, upstream, mechanical, scrape.