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(54) Title: FINISHING SYSTEMS AND METHODS THEREOF

(57) Abstract: The systems and methods provided herein include supplying a polymer product of a polymerization reactor to a purge bin, wherein the polymer product comprises one or more non-polymer components. The polymer product is transferred to a screener. A first non-polymer component content is determined at a first location using a first sensor. The first location is disposed on a first convey line downstream of the screener or is disposed on the screener. The polymer product is transferred to a feed bin. A non-polymer component is removed using a first recovery line disposed on or near the feed bin. A second non-polymer component content is determined at a second convey line using a second sensor. The second location is disposed on a second convey line downstream of the feed bin and upstream of an extruder.



FINISHING SYSTEMS AND METHODS THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application Number 63/612,628, filed on December 20, 2023, entitled "Finishing Systems and Methods Thereof", the entirety of which is incorporated by reference herein.

FIELD OF INVENTION

[0002] The present disclosure generally relates to finishing systems and methods of producing polyolefins.

BACKGROUND

[0003] Polyolefin syntheses often include a monomer and a comonomer where the comonomer has a higher carbon-number than the monomer. For example, a polyethylene may be synthesized using ethylene monomer, 1-hexene comonomer, and a catalyst. The comonomer is typically high purity (*e.g.*, 99%) and includes impurities that are primarily inert isomers (in the prescribed reaction) and saturates of the comonomer (*e.g.*, 2-cis-hexene and hexane, respectively).

[0004] In a polyolefin synthesis after polymerization, for example in a gas-phase reactor, the product stream is separated into a polymer stream and an unreacted components stream. The polymer stream can have impurities that are present in the polymer product(s), such as unpolymerized components originating from unreacted monomers, unreacted comonomers, or other impurities, *e.g.*, inert isomers, saturates of the comonomer, or one or more other hydrocarbons. Generally, the non-polymer components are stripped from the products in the purge bin using a purge gas such as nitrogen. Unfortunately, not all of the non-polymer components, *e.g.*, hydrocarbons, are stripped as the purge gas reaches an equilibrium minimum amount, *e.g.*, about 50 to about 100 ppmw of hydrocarbons. The stripped product containing residual non-polymer components is then transferred to a finishing system using a convey line.

[0005] Unfortunately, the convey line is open to atmosphere, allowing the low amount of non-polymer components, *e.g.*, hydrocarbons, remaining in the stripped product to emit to atmosphere. Moreover, attempts to recycle these non-polymer components have been uneconomical due to the low concentrations of non-polymer components present in the polymer product(s).

[0006] There is a need for improved systems capable of reducing non-polymer components in polymer product(s) that would otherwise be emitted to atmosphere.

SUMMARY OF INVENTION

[0007] In some embodiments, the methods provided herein include supplying a polymer product of a polymerization reactor to a purge bin. The polymer product includes one or more non-polymer components. The polymer product is transferred to a screener. A first non-polymer component content is determined at a first location using a first sensor. The first location is disposed on a first convey line downstream of the screener or is disposed on the screener. The polymer product is transferred to a feed bin. A non-polymer component is removed using a first recovery line disposed on or near the feed bin. A second non-polymer component content is determined at a second convey line using a second sensor. The second location is disposed on a second convey line downstream of the feed bin and upstream of an extruder.

[0008] In some embodiments, finishing systems of a polymerization reactor include a first convey line fluidly coupled to an inlet of a screener. A second convey line is fluidly coupled to an outlet of the screener and an inlet of a feed bin. A third convey line is fluidly coupled to an outlet of the feed bin and an inlet of an extruder. A fourth convey line is fluidly coupled to an outlet of the extruder and an inlet of a collector. A first recovery line is fluidly coupled to the feed bin, extruder, or collector. A first sensor is fluidly coupled to a first location, second location, or third location along the first convey line, the second convey line, or the third convey line.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The following figures are included to illustrate certain aspects of the embodiments and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, as will occur to those skilled in the art and having the benefit of this disclosure.

[0010] FIG. 1 depicts a schematic of an illustrative gas phase polymerization system for making polymers according to embodiments of the present disclosure.

[0011] FIG. 2 depicts a schematic of an illustrative finishing system according to embodiments of the present disclosure.

[0012] While the disclosed process and system are susceptible to various modifications and alternative forms, the drawing illustrates a specific embodiment herein described in detail by way of example. It should be understood, however, that the description herein of a specific embodiment is not intended to limit the present disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure as defined by the appended claims.

DETAILED DESCRIPTION

[0013] The present disclosure provides improved polyolefin syntheses utilizing improved finishing systems of polymer products to recover one or more non-polymer components, *e.g.*, hydrocarbons, from a convey line of a gas-phase polymerization system, preventing emission
5 of non-polymer components or other hydrocarbons and/or volatile organic compounds (VOCs) into the atmosphere. VOCs can include any organic (carbon-containing) compound which can evaporate under standard atmospheric temperature and pressure (STP), other than CO₂, CO, carbonic acid, and certain carbides/carbonates (*e.g.*, metallic carbides or carbonates and ammonium carbonate), and in particular VOCs of relevance herein may be hydrocarbon VOCs.
10 The one or more recovered non-polymer components may be sent to a combustion or thermal oxidation system, which may convert all or substantially all of the non-polymer components to CO₂ and H₂O.

[0014] The present disclosure also provides a finishing system that removes non-polymer components, *e.g.*, hydrocarbons and/or other VOCs, along locations of a convey line of the
15 finishing system, which reduces and/or eliminates VOCs from escaping to the atmosphere. The locations may be locations identified as having high concentrations of non-polymer components along the convey line, such that the finishing system may efficiently remove the non-polymer components from the convey line. Removal in this context can include sending such components to a control device (*e.g.*, flare, thermal oxidizer, and/or boiler) for conversion
20 to other compounds (such as combustion to CO₂ and H₂O), and/or capturing for recycling and/or storage in another part of the system or another system.

[0015] Illustrative embodiments of the subject matter claimed below will now be disclosed. In the interest of clarity, some features of some actual implementations may not be described in this specification. It will be appreciated that in the development of any such actual
25 embodiments, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort, even if complex and time-consuming, would be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

30 [0016] The words and phrases used herein should be understood and interpreted to have a meaning consistent with the understanding of those words and phrases by those skilled in the relevant art. No special definition of a term or phrase, *e.g.*, a definition that is different from the ordinary and customary meaning as understood by those skilled in the art, is intended to be implied by consistent usage of the term or phrase herein.

Definitions

[0017] “Inert gas,” as used herein, refers to a gas that does not readily undergo chemical reactions with one or more of the reactants, monomers, comonomers, catalysts, or other chemical substance in a gas-phase polymerization reactor.

5 [0018] “Carrier gas,” as used herein refers to a gas that carries at least a nominal amount of a first component, *e.g.*, unreacted components, to a gas-phase polymerization reactor. In at least an embodiment, the carrier gas is an inert gas. In at least an embodiment, the carrier gas is a gas capable of reacting with non-polymer component(s) and/or polymer component(s).

[0019] An “olefin,” alternatively referred to as “alkene,” is a linear, branched, or cyclic
10 compound of carbon and hydrogen having at least one double bond. For purposes of this specification and the claims appended thereto, when a polymer or copolymer is referred to as comprising an olefin, the olefin present in such polymer or copolymer is the polymerized form of the olefin. For example, when a copolymer is said to have an “ethylene” content of 35 wt% to 55 wt%, it is understood that the mer unit in the copolymer is derived from ethylene in the
15 polymerization reaction and said derived units are present at 35 wt% to 55 wt%, based upon the weight of the copolymer. A “polymer” has two or more of the same or different mer units. A “homopolymer” is a polymer having mer units that are the same. A “copolymer” is a polymer having two or more mer units that are different from each other. A “terpolymer” is a polymer having three mer units that are different from each other. Accordingly, the definition
20 of copolymer, as used herein, includes terpolymers and the like. “Different” as used to refer to mer units indicates that the mer units differ from each other by at least one atom or are different isomerically. An “ethylene polymer” or “ethylene copolymer” is a polymer or copolymer comprising at least 50 mol% ethylene derived units, a “propylene polymer” or “propylene copolymer” is a polymer or copolymer comprising at least 50 mol% propylene derived units,
25 and so on.

[0020] Ethylene shall be considered an α -olefin.

[0021] Unless otherwise specified, the term “C_n” means hydrocarbon(s) having n carbon atom(s) per molecule, wherein n is a positive integer.

[0022] The term “hydrocarbon” means a class of compounds containing hydrogen bound
30 to carbon, and encompasses (i) saturated hydrocarbon compounds, (ii) unsaturated hydrocarbon compounds, and (iii) mixtures of hydrocarbon compounds (saturated and/or unsaturated), including mixtures of hydrocarbon compounds having different values of n. Likewise, a “C_m-C_y” group or compound refers to a group or compound comprising carbon

atoms at a total number thereof in the range from m to y. Thus, a C₁-C₅₀ alkyl group refers to an alkyl group comprising carbon atoms at a total number thereof in the range from 1 to 50.

[0023] "Catalyst," as used in the method disclosed herein, is the same catalyst throughout the method. That is to say, that the catalyst used for making the first polyethylene will be the same catalyst used for making the second polyethylene, and inherently any transitional polyethylene produced using the gas-phase polymerization process.

[0024] "C_n" as used herein, and unless otherwise specified, the term means hydrocarbon(s) having n carbon atom(s) per molecule, wherein n is a positive integer.

[0025] "Induced condensing agent (ICA)," as used herein, means one or more inert condensable fluids which are readily volatile liquid hydrocarbons, which may be selected from saturated hydrocarbons containing from 2 to 10 carbon atoms, such as 3 to 10 carbon atoms. Some suitable saturated hydrocarbons are propane, n-butane, isobutane, n-pentane, isopentane, neopentane, n-hexane, isohexane, and other saturated C₆ hydrocarbons, n-heptane, n-octane and other saturated C₇ and C₈ hydrocarbons or mixtures thereof. A class of exemplary inert condensable hydrocarbons are C₅ and C₆ saturated hydrocarbons. Another class of exemplary hydrocarbons are C₄ to C₆ saturated hydrocarbons. Exemplary hydrocarbons for use as condensable fluids include pentanes, such as isopentane. The condensable fluids may also include polymerizable condensable comonomers such as olefins, diolefins or mixtures thereof including some of the monomers mentioned herein which may be partially or entirely incorporated in the polymer product.

[0026] "Efficiency," as used herein, refers to the amount of actual polymer product that is produced as a result of the gas-phase polymerization reaction compared to the amount of non-polymer components, *e.g.*, unreacted monomers and unreacted comonomers that remain in the product after polymerization, for example, hydrogenated monomers or comonomers and/or un-polymerized monomers or comonomers. Efficiency may be represented by a w/v % of the total product formed. For example, a polymerization may have an efficiency of 90% where the reactants polymerized to produce 90 w/v% product and 10 w/v% of non-polymer components.

[0027] "Production rate," as used herein, refers to the amount of polymer product produced per unit time based on the amount of reactant that is introduced into the polymerization reactor, where the unit time may be represented by seconds, minutes, hours, days, or the like.

[0028] "Polyethylene," as used herein, means an ethylene homopolymer or a copolymer comprising at least 50 wt% ethylene. The terms "polyethylene polymer," "polyethylene," "ethylene polymer," "ethylene copolymer," and "ethylene-based polymer" have the same meaning as polyethylene copolymer, except where otherwise indicated (*e.g.*, where a

polyethylene homopolymer is referred to, this means a polymer formed from ethylene monomer without comonomer units, e.g., 100 wt% ethylene-derived units).

[0029] “Polymerization conditions,” as used herein, means conditions conducive to the reaction of one or more olefin monomers when contacted with an activated olefin polymerization catalyst to produce a polyolefin polymer, including a skilled artisan’s selection of temperature, pressure, reactant concentrations, optional solvent/diluents, reactant mixing/addition parameters, and other conditions within at least one polymerization reactor.

[0030] “Reactor system,” as used herein, means the reactor and piping and equipment containing the circulating loop of cycle fluid, including, the cycle fluid heat exchanger.

Polymerization Process

[0031] The present disclosure provides methods for recovering non-polymer components or other hydrocarbons and/or VOCs. During normal operations, a gas phase polymerization process comprises continuous addition of a catalyst, ethylene monomer, and optionally one or more comonomers and/or hydrogen, to a fluidized bed in a polymerization reaction zone under a set of polymerization conditions and withdrawing a polyethylene product having a density and melt index (I_2).

[0032] FIG. 1 depicts a flow diagram of an illustrative gas phase polymerization system 100 for making polymers, according to one or more embodiments. The polymerization system 100 includes a reactor 101 in fluid communication with one or more discharge tank(s) 155 (only one shown), compressor(s) 170 (only one shown), heat exchanger(s) 175 (only one shown), purge bin(s) 180 (only one shown), and purge gas recovery unit(s) 182 (only one shown). The polymerization system 100 can also include more than one reactor 101 arranged in series, parallel, or configured independent from the other reactors, each reactor having its own associated discharge tank(s) 155, compressor(s) 170, heat exchanger(s) 175, purge bin(s) 180, or purge gas recovery unit(s) 182 or alternatively, sharing any one or more of the associated discharge tank(s) 155, compressor(s) 170, heat exchanger(s) 175, purge bin(s) 180, or purge gas recovery unit(s) 182. For simplicity and ease of description, the polymerization system 100 will be further described in the context of a single reactor train.

[0033] The conditions for polymerizations in the reactor 101 vary depending upon the monomers, catalysts, catalyst systems, and equipment availability. For example, the temperatures can be within the range of from about -10°C to about 140°C , often about 15°C to about 120°C , and more often about 70°C to about 110°C . Pressures can be within the range of from about 10 kPag to about 10,000 kPag, such as about 500 kPag to about 5,000 kPag, or about 1,000 kPag to about 2,200 kPag, for example.

[0034] The reactor 101 can include a cylindrical section 103, a transition section 105, and a velocity reduction zone or dome 107. The cylindrical section 103 is disposed adjacent the transition section 105. The transition section 105 can expand from a first diameter that corresponds to the diameter of the cylindrical section 103 to a larger diameter adjacent the dome 107. As mentioned above, the location or junction at which the cylindrical section 103 connects to the transition section 105 is referred to as the “neck” or the “reactor neck” 104. The dome 107 has a bulbous shape. One or more cycle fluid lines 115 and vent lines 118 can be in fluid communication with the top head 107. The reactor 101 can be free from the use of stirring and/or wall scraping. The reactor 101 can include the fluidized bed 112 in fluid communication with the top head 107.

[0035] In general, the height to diameter ratio of the cylindrical section 103 can vary in the range of from about 2:1 to about 5:1. The range, of course, can vary to larger or smaller ratios and depends, at least in part, upon the desired production capacity and/or reactor dimensions. The cross-sectional area of the dome 107 is typically within the range of from about 2 to about 3 multiplied by the cross-sectional area of the cylindrical section 103.

[0036] The velocity reduction zone or dome 107 has a larger inner diameter than the fluidized bed 112. As the name suggests, the velocity reduction zone 107 slows the velocity of the gas due to the increased cross-sectional area. This reduction in gas velocity allows particles entrained in the upward moving gas to fall back into the bed, allowing primarily only gas to exit overhead of the reactor 101 through the cycle fluid line 115. The cycle fluid recovered via line 115 can contain less than about 10 wt%, less than about 8 wt%, less than about 5 wt%, less than about 4 wt%, less than about 3 wt%, less than about 2 wt%, less than about 1 wt%, less than about 0.5 wt%, or less than about 0.2 wt% of the particles entrained in fluidized bed 112 over a period of time, *e.g.*, about less than 10 wt% in mass per unit time. The cycle line 115 and the elements therein (compressor 170, heat exchanger 175) can be smooth surfaced and devoid of unnecessary obstructions so as not to impede the flow of cycle fluid or entrained particles.

[0037] The reactor feed via line 110 can be introduced to the polymerization system 100 at any point. For example, the reactor feed via line 110 can be introduced to the cylindrical section 103, the transition section 105, the velocity reduction zone 107, to any point within the cycle fluid line 115, or any combination thereof. Figure 1 depicts the reactor feed via line 110 entering the cycle fluid in line 115 after the heat exchanger 175, however the reactor feed via line 110 may be implemented in one or more alternative locations, *e.g.*, before the heat exchanger 175 or after the heat exchanger 175. The catalyst feed via line 113 can be introduced

to the polymerization system 100 at any point. For example, the catalyst feed via line 113 is introduced to the fluidized bed 112 within the cylindrical section 103.

[0038] During normal operation, *e.g.*, polymer production, under a given set of operating conditions, the fluidized bed may be maintained at essentially a constant height by withdrawing a portion of the bed as polymer product at the rate of formation of the particulate polymer product. Since the rate of heat generation during polymerization is directly related to the rate of product formation, a temperature rise of the fluid across the reactor (the difference in temperature between reactor feed line 110 and exit cycle fluid via line 115) is indicative of the rate of particulate polymer formation at a constant fluid velocity if no or negligible vaporizable liquid is present in the inlet fluid.

[0039] The reactor feed line 110 feeds one or more unreacted monomers or unreacted comonomers in a cycle gas stream. The cycle gas stream may include a cycle gas having a heat capacity, *e.g.*, greater than 130 J/molK, to ensure that the DT is maintained, which will assist in producing a higher rate of particular polymer formation. For example, the cycle gas stream that carries the one or more unreacted monomers or unreacted comonomers through the reactor feed line 110 can include ethane, ethylene, methane, or the like. For example, a cycle gas may include an ethane gas in an amount of about 95% v/v ethane to about 100 % v/v ethane, such as about 95% v/v, about 96% v/v, about 97% v/v, about 97% v/v, about 99% v/v, or about 100% v/v, low impurities, *e.g.*, about 0.0% v/v to about 10% v/v, such as about 0.01% v/v, about 0.1% v/v, about 1% v/v, about 2% v/v, about 4% v/v, about 6% v/v, about 8% v/v, or about 10% v/v, a low olefinic content, *e.g.*, about 0.0% v/v to about 10% v/v, such as about 0.01% v/v, about 0.1% v/v, about 1% v/v, about 2% v/v, about 4% v/v, about 6% v/v, about 8% v/v, or about 10% v/v. In at least one embodiment, the cycle gas including ethane gas may have a low temperature, *e.g.*, about 40 °F to about 120 °F, such as about 60 °F to about 100 °F, 80 °F to about 90 °F, or about 40 °F to about 100 °F. In at least embodiment, the carrier gas including ethylene gas may have a low temperature, *e.g.*, about -10 °F to about 40 °F, such as about -10 °F to about 10 °F, 10 °F to about 30 °F, or about 20 °F to about 40 °F.

[0040] The cycle fluid via line 115 can be compressed in the compressor 170 and then passed through the heat exchanger 175 where heat can be exchanged between the cycle fluid and a heat transfer medium. For example, during normal operating conditions a cool or cold heat transfer medium via line 171 can be introduced to the heat exchanger 175 where heat can be transferred from the cycle fluid in line 115 to produce a heated heat transfer medium via line 177 and a cooled cycle fluid via line 115. In another example, during idling of the reactor 101 a warm or hot heat transfer medium via line 171 can be introduced to the heat exchanger

175 where heat can be transferred from the heat transfer medium to the cycle fluid in line 115 to produce a cooled heat transfer medium via line 177 and a heated cycle fluid via line 115. The terms “cool heat transfer medium” and “cold heat transfer medium” refer to a heat transfer medium having a temperature less than the fluidized bed 112 within the reactor 101. The terms
5 “warm heat transfer medium” and “hot heat transfer medium” refer to a heat transfer medium having a temperature greater than the fluidized bed 112 within the reactor 101. The heat exchanger 175 can be used to cool the fluidized bed 112 or heat the fluidized bed 112 depending on the particular operating conditions of the polymerization system 100, *e.g.*, reactor start-up, normal operation, idling, and shut down. For example, the heat exchanger 175 can cool the
10 cycle fluid in line 115 to about 100 °C to about 250 °C or lower. Alternatively, the heat exchanger 175 can heat the cycle fluid in line 115 to about 50 °C to about 500 °C, *e.g.*, about 50 °C to about 100 °C, about 100 °C to about 300 °C, or about 300 °C to about 500 °C. Illustrative heat transfer mediums can include water, air, glycols, or the like. It is also possible to locate the compressor 170 downstream from the heat exchanger 175 or at an intermediate
15 point between several heat exchangers 175.

[0041] After cooling, all or a portion of the cycle fluid via line 115 can be returned to the reactor 101. The cooled cycle fluid in line 115 can absorb the heat of reaction generated by the polymerization reaction. The heat transfer medium in line 171 can be used to transfer heat to the cycle fluid in line 115 thereby introducing heat to the polymerization system 100 rather
20 than removing heat therefrom. The heat exchanger 175 can be of any type of heat exchanger. Illustrative heat exchangers can include shell and tube, U-tube, and the like. For example, the heat exchanger 175 can be a shell and tube heat exchanger where the cycle fluid via line 115 can be introduced to the tube side and the heat transfer medium can be introduced to the shell side of the heat exchanger 175. If desired, several heat exchangers can be employed, in series,
25 parallel, or a combination of series and parallel, to lower or increase the temperature of the cycle fluid in stages.

[0042] In some embodiments, the cycle gas via line 115 is returned to the reactor 101 and to the fluidized bed 112 through fluid distributor plate (“plate”) 119. The plate 119 can be installed at the inlet to the reactor 101 to prevent polymer particles from settling out and
30 agglomerating into a solid mass and to prevent liquid accumulation at the bottom of the reactor 101 as well to facilitate easy transitions between processes which contain liquid in the cycle stream 115 and those which do not and vice versa. Although not shown, the cycle gas via line 115 can be introduced into the reactor 101 through a deflector disposed or located intermediate an end of the reactor 101 and the distributor plate 119.

[0043] The catalyst feed via line 113 can be introduced to the fluidized bed 112 within the reactor 101 through one or more injection nozzles (not shown) in fluid communication with line 113. The catalyst feed is introduced as pre-formed particles in one or more liquid or gas carriers (*e.g.*, a catalyst slurry or a particle in a gas). Suitable liquid carriers can include mineral oil and/or liquid or gaseous hydrocarbons including propane, butane, isopentane, hexane, heptane octane, or mixtures thereof. Suitable gas carriers include carrier gases that have a higher heat capacity and/or gas density value, *e.g.*, ethane, ethylene, or a combination thereof, to provide a higher temperature during the polymerization reaction, which increases the temperature at the velocity reduction zone or dome 107 and drives the reaction to produce more products at a higher efficiency. For example, the gas carrier of line 113 may include about 20% ethylene to about 100% ethylene, *e.g.*, about 20% v/v to about 40% v/v, about 30% v/v to about 50% v/v, about 40% v/v to about 60% v/v, about 50% v/v to about 70% v/v, about 60% v/v to about 80% v/v, about 70% v/v to about 90% v/v, or about 80% v/v to about 100% v/v. As a further example, the gas carrier of line 113 may include about 0% ethane to about 100% ethane, *e.g.*, about 0% v/v to about 20% v/v, about 10% v/v to about 30% v/v, about 20% v/v to about 40% v/v, about 30% v/v to about 50% v/v, about 40% v/v to about 60% v/v, about 50% v/v to about 70% v/v, about 60% v/v to about 80% v/v, about 70% v/v to about 90% v/v, or about 80% v/v to about 100% v/v. The gas carrier can also be used to carry the catalyst slurry into the reactor. In one example, the catalyst can be a dry powder. In another example, the catalyst can be dissolved in a liquid carrier and introduced to the reactor 101 as a solution. The catalyst via line 113 can be introduced to the reactor 101 at a rate sufficient to maintain polymerization of the monomer(s) therein. Hydrogen can be added via line 114.

[0044] Alternatively, the carrier gas could potentially be vaporized (gaseous) isobutane. If isobutane is used in this manner, it would preferably be separated (*e.g.*, in the downstream recovery unit 182), and preferably sent to a separate process (for instance, potentially an olefins production process upstream of the polymerization reaction system) to avoid potential accumulation of this non-reaction-participating substance in the system. If not separated and/or removed from the system in this manner, then the isobutane in the system could require flaring for inert control. If handled appropriately downstream (*e.g.*, as just discussed), this substitution versus nitrogen could further improve cycle gas density and heat capacity, allowing for increased production rate of polymer product.

[0045] Fluid via line 161 can be separated from a polymer product recovered via line 117 from the reactor 101. The fluid can include unreacted monomer(s), hydrogen, induced condensing agents (ICAs), and/or inerts, such as ethane and/or ethylene. The separation of the

fluid can be accomplished when fluid and/or product leave the reactor 101 and enter the product discharge tank 155 (one is shown) through valve 157, which can be, for example, a ball valve designed to have minimum restriction to flow when opened. Positioned above and below the product discharge tank 155 can be conventional valves 159, 167. The valve 167 allows passage of product therethrough. For example, to discharge the polymer product from the reactor 101, valve 157 can be opened while valves 159, 167 are in a closed position. Product and fluid enter the product discharge tank 155. Valve 157 is closed and the product is allowed to settle in the product discharge tank 155. Valve 159 is then opened permitting fluid to flow via line 161 from the product discharge tank 155 to the reactor 101. Valve 159 can then be closed and valve 167 can be opened and any product in the product discharge tank 155 can flow into and be recovered via line 168. Valve 167 can then be closed. The particular timing sequence of the valves 157, 159, and 167 can be accomplished by use of conventional programmable controllers which are well known in the art. The fluid via line 161 can be introduced to the reactor 101. Alternatively, the fluid via line 161 can be introduced to the recycle line 115 (not shown).

[0046] The product via line 168 can be introduced to a purge bin 180 (only one is shown). Alternatively, the product line 168 can be introduced to a plurality of separation units, in series, parallel, or a combination of series and parallel, to further separate gases and/or liquids from the product. The purge bin 180 may receive the product via line 168, in which a plurality of gas stripping streams within the purge bin 180 may direct one or more purge vent streams via line 184 to a purge gas recovery unit 182. For example, the gas stripping stream may include about 20% ethylene to about 100% ethylene, *e.g.*, about 20% v/v to about 40% v/v, about 30% v/v to about 50% v/v, about 40% v/v to about 60% v/v, about 50% v/v to about 70% v/v, about 60% v/v to about 80% v/v, about 70% v/v to about 90% v/v, or about 80% v/v to about 100% v/v. As a further example, the gas stripping stream may include about 0% ethane to about 100% ethane, *e.g.*, about 0% v/v to about 20% v/v, about 10% v/v to about 30% v/v, about 20% v/v to about 40% v/v, about 30% v/v to about 50% v/v, about 40% v/v to about 60% v/v, about 50% v/v to about 70% v/v, about 60% v/v to about 80% v/v, about 70% v/v to about 90% v/v, or about 80% v/v to about 100% v/v.

[0047] In at least one embodiment, the purge bin 180 includes a region comprising a rotary feeder and a nitrogen gas inlet to prevent one or more hydrocarbons from leaking out of the purge bin. The rotary feeder may direct one or more polymer products from the purge bin to a finishing system via a convey line 198, where the finishing system is described below with

reference to FIG. 2. Additionally, the purge bin 180 may direct one or more purge gases, *e.g.*, hydrogen, to a hydrogen recovery plant, such as a blue hydrogen plant, via line 199.

[0048] The purge vent streams in line 184 can have a concentration of non-polymer components, such as one or more unreacted monomers, unreacted comonomers, or other hydrocarbons and/or VOCs, or catalytic components ranging from about 1 ppmw to about 500 ppmw. For example, the purge vent streams in line 184 can have a concentration of one or more catalytic components ranging from a low of about 1 ppmw to about 25 ppmw of unreacted monomer, unreacted comonomer, other hydrocarbons and/or VOCs, and catalytic components to a high of about 25 ppm to about 500 ppmw of unreacted monomer, unreacted comonomer, other hydrocarbons and/or VOCs, and catalytic component. In at least one embodiment, the purge vent stream in line 184 can be a purge gas that is free of or essentially free of unreacted monomers, unreacted comonomers, other hydrocarbons and/or VOCs, and catalytic components, *e.g.*, less than about 1 ppmw, less than about 0.5 ppmw, or less than about 0.1 ppmw.

[0049] The fluid in line 184 may be processed in the purge gas recovery unit 182. The purge gas recovery unit 182 may receive a makeup gas stream from a line 186 to assist in cooling the fluid in line 184. The makeup gas stream may include one or more makeup gases capable of cooling the fluid in line 184. For example, the makeup stream may include a makeup gas such as argon, nitrogen, ethane, ethylene, or methane. For example, the makeup gas may include about 20% ethylene to about 100% ethylene, *e.g.*, about 20% v/v to about 40% v/v, about 30% v/v to about 50% v/v, about 40% v/v to about 60% v/v, about 50% v/v to about 70% v/v, about 60% v/v to about 80% v/v, about 70% v/v to about 90% v/v, or about 80% v/v to about 100% v/v. As a further example, the makeup gas may include about 0% ethane to about 100% ethane, *e.g.*, about 0% v/v to about 20% v/v, about 10% v/v to about 30% v/v, about 20% v/v to about 40% v/v, about 30% v/v to about 50% v/v, about 40% v/v to about 60% v/v, about 50% v/v to about 70% v/v, about 60% v/v to about 80% v/v, about 70% v/v to about 90% v/v, or about 80% v/v to about 100% v/v. The makeup gas stream may be introduced in the recovery unit 180 at a lower pressure than the pressure of line 184, such that the drop in pressure results in a further chilling of the fluid in line 184.

[0050] A recovery fluid in line 188 may leave the purge gas recovery unit 182, in which the recovery fluid may be introduced to the reactor 101 via line 190 or may be introduced back to the purge bin via line 196. Alternatively, the recovery fluid 188 may be introduced to the recycle line 115 (not shown). The recovery fluid in line 188 may be regulated by one or more

valves 190. The one or more valves 190 may limit or restrict a flow of the recovery fluid in line 188 from being introduced to the reactor 101 or the recycle line 115 (not shown).

[0051] The recovery fluid in line 188 may be diverted through an exhaust valve 192. The exhaust valve 192 may open or close an exhaust line 194. The exhaust line 194 may transmit fluid to flare. Alternatively, the exhaust line 194 may be transferred to an olefins processing plant to perform one or more hydrocarbon recovery processes. In at least one embodiment, the recovery fluid in line 194 may have a low nitrogen content, *e.g.*, about 1% v/v to about 10% v/v, *e.g.*, about 1% v/v to about 3% v/v, about 2% v/v to about 4% v/v, about 5% v/v to about 7% v/v, about 6% v/v to about 8 % v/v, about 7% v/v to about 9 % v/v, or about 8% v/v to about 10% v/v.

[0052] One embodiment of a product discharge system employs at least one (parallel) pair of tanks comprising a settling tank and a transfer tank arranged in series and having the separated gas phase returned from the top of the settling tank to a point in the reactor near the top of the fluidized bed.

Recovery Unit

[0053] Returning to FIG. 1, a purge vent stream via line 184 may exit the purge bin 180 and be introduced to the recovery unit 182. The recovery unit may include a cooler. The cooler may include a heat exchanger as described above. For example, during normal operating conditions a hot or warm purge vent stream via line 184 may be introduced to the cooler of the recovery unit 182 where heat is transferred from the hot or warm purge vent stream to the cooler via a heat transfer medium. The heat transfer medium may include any suitable material that is capable of absorbing the heat emitted by the hot or warm purge vent stream. For example, and without limitation, the cooler may include a chilled water system capable of absorbing the heat from the purge vent stream.

[0054] The cooler can produce a purge vent stream in line 184 having a temperature of about 15 °C to about 60 °C, *e.g.*, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, or about 55 °C to about 60 °C. Without being bound by theory, when the purge vent stream in line 184 is cooled, the pressure will drop. As such, the purge vent stream in line 184 is sent to a compressor of the recovery unit 182 from the cooler to allow for a controlled temperature increase downstream.

[0055] The compressor can compress the purge vent stream to produce compressed purge gas. The compressed purge gas can be at a pressure of about 60 psi to about 500 psi, *e.g.*, about 60 psi to about 100 psi, about 100 psi to about 150 psi, about 150 psi to about 200 psi, about

200 psi to about 250 psi, about 250 psi to about 300 psi, about 350 psi to about 400 psi, about 400 psi to about 450 psi, or about 450 psi to about 500 psi. For example, the compressed purge gas can be at a pressure ranging from a low pressure of about 60 psi to about 100 psi to a high pressure of about 100 psi to about 500 psi.

5 [0056] During compression of the purge vent stream within the compressor of the recovery unit the temperature of the purge gas can be maintained below a predetermined maximum temperature. The maximum temperature can be based, at least in part, on the particular make-up or composition of the purge gas product in line 184. For example, if the purge vent stream includes catalytic components such as triethylaluminum (TEAL) and one or more olefins, the
10 predetermined maximum temperature could be about 140 °C, because if the purge gas product is heated to higher temperatures, polymerization could be initiated within the compressor. Depending, at least in part, on the particular composition of the purge vent stream, *e.g.*, the presence of catalytic components and/or the concentration of catalytic components in the purge vent stream, the temperature of the purge vent stream can be maintained below about 100 °C
15 to about 250 °C, *e.g.*, about 100 °C to about 125 °C, about 125 to about 150 °C, about 150 °C to about 175 °C, about 175 °C to about 200 °C, about 200 °C to about 225 °C, about 225 °C to about 250 °C during compression.

[0057] The compressor can compress the purge vent stream in line 184 at any desired pressure ratio, *e.g.*, any desired ratio of the pressure of the purge vent stream introduced to the
20 compressed compared to the pressure of the compressed purge gas recovered from the compressor. For example, a purge vent stream in line 184 may have a pressure of about 110 kPa in line 184 entering the compressor of the recovery unit 182, in which the compressed purge gas exiting the compressor of the recovery unit 182 may have a pressure of about 385 kPa, which would be a ratio of about 1:3.5. The compressor of the recovery unit 182 can
25 compress the purge vent stream at a pressure ratio ranging from about 1:2 to about 1:10, *e.g.*, about 1:2 to about 1:4, about 1:3 to about 1:5, about 1:4 to about 1:6, about 1:5 to about 1:7, about 1:6 to about 1:8, about 1:7 to about 1:9, or about 1:8 to about 1:10. Without being bound by theory, the pressure ratio within the compressor of the recovery unit 182 can be based, at least in part, on the desired pressure of the compressed purge gas, the type of compressor, the
30 desired predetermined maximum temperature of the compressed purge gas after compression, or any combination thereof.

[0058] The compressed purge gas may have a temperature that is based on the amount of compression in the compressor and the temperature of the purge vent stream in line 184 after exiting the cooler of the recovery unit 182. As the purge vent stream in line 184 is compressed

the partial pressure of the unreacted monomers, unreacted comonomers, impurities, and catalytic components increases, such as hydrogenated monomers or comonomers and/or un-polymerized monomers or comonomers. As such, the potential for polymerization initiating increases, requiring control of the maximum temperature of the compressed purge gas. By
5 controlling the pressure ratio of the compressor, the temperature of the compressed purge gas may be controlled, in which a temperature that is below the maximum temperature may be produced, limiting polymerization in the compressor of the recovery unit 182.

[0059] The compressed purge gas is introduced to an interchanger in the recovery unit 182. The interchanger may direct the compressed purge gas to a water cooler and a condenser to
10 condense liquid hydrocarbons. The interchanger may include a series of diverters or valves capable of directing or redirecting the compressed purge gas.

[0060] The water cooler can reduce the temperature of the compressed purge gas from a temperature range of about 100 °C to about 250 °C to a temperature range of about 20 °C to about 50 °C, *e.g.*, about 20 °C to about 30 °C, about 30 °C to about 40 °C, or about 40 °C to
15 about 50 °C.

[0061] The cooled compressed purge gas is introduced to one or more condensers of the recovery unit 182 to produce a gas product and a condensed product. The condenser can reduce the temperature of the compressed purge gas to a temperature range of about -30 °C to about 0 °C, *e.g.*, about -30 °C to about -20 °C, about -20 °C to about -10 °C, or about -10 °C to about
20 0 °C. In at least an embodiment, the condenser can reduce the temperature of the compressed purge gas using a refrigeration system or integrated letdown system. The condensers can be or include any system, device, or combination of systems and/or devices suitable for separating gas from liquids. For example, the condensers can be or include one or more flash tanks, distillation columns, fractionation columns, divided wall columns, or any combination thereof.
25 The condensers can contain one or more internal structures including trays, random packing elements such as rings or saddles, structured packing, or any combination thereof. The condensers can be or include an open column without internals. The condensers can be a partially empty column containing one or more internal structures. Without being bound by theory, due to the use of ethane, a distillation column, fractionation column, or condenser may
30 be used to separate hydrocarbons without the need for a cryogenic distillation, pressure swing adsorption, or membrane technology which can reduce processing costs during gas-phase polymerization reactions.

[0062] The gas product of the condenser is reintroduced to the interchanger, which may recycle the gas product for the gas-phase polymerization reaction. The gas product in line can

be at a temperature of about -30 °C to about -10 °C, e.g., about -30 °C to about -25 °C, about -25 °C to about -20 °C, about -20 °C to about -15 °C, or about -15 °C to about -10 °C.

[0063] The condensed product of the condenser can include one or more of the heavier hydrocarbons contained in the purge gas vent stream in line 184. For example, when the purge gas vent stream in line 184 contains ethylene and one or more comonomers such as butene, hexene, and/or octene, the major component(s) of the condensed fluids of the condenser can include the one or more comonomers. As used herein, the term "major component" refers to a component of composition that is present in the composition in more than trace amounts, e.g., greater than 100 parts per million (ppm). When the purge gas vent stream in line 184 contains ethylene and one or more inert hydrocarbons, e.g., solvents, diluents, or induced condensing agents (ICAS), such as propane, butane, pentane, hexane, and/or octane, the major component(s) of the condensed fluids of the condenser can be the inert hydrocarbons. In another example, when the purge gas vent stream in line 184 contains ethylene, one or more comonomers, and one or more inert hydrocarbons, the major component(s) of the condensed fluids of the condenser can be the comonomer(s) and the inert hydrocarbons.

[0064] Depending, at least in part, on the particular composition of the purge gas vent stream in line 184, the composition of the condensed fluids in the condenser can widely vary. When the purge gas product contains inert hydrocarbons, e.g., iso-pentane, the concentration of the inert hydrocarbons can range from a low of about 20 wt %, about 25 wt %, or about 30 wt % to a high of about 60 wt %, about 70 wt %, about 80 wt %, about 90 wt %, or about 95 wt %. When the purge gas product contains comonomers, the concentration of comonomers, e.g., butene, hexene, and/or octene, can range from a low of about 10 wt %, about 20 wt %, or about 30 wt % to a high of about 40 wt %, about 50 wt %, about 60 wt %, about 70 wt %, about 80 wt %, about 90 wt %, or about 95 wt %.

[0065] All or a portion of the condensed fluid of the condenser can be recycled to the polymerization reactor 101. The condensed fluid recovered from the condenser can be recycled via line 188 to the polymerization reactor and/or introduced to the cycle fluid lines 115, not shown.

[0066] The gas product of the condenser may be recycled back to the interchanger. The gas product of the condenser may be recycled and mixed with the makeup gas 186 to provide a fresh makeup gas that may assist in additional cooling of the compressed purge gas that enters the interchanger. The interchanger may divert the gas product of the condenser to return to the water cooler. Alternatively, the interchanger may direct the gas product of the condenser to be sent to line 188 where it may be recycled via line 196 or vented or flared via line 194. For

example, all or a portion of the gas product via line 188 can be vented, flared, combusted to generate heat, or otherwise disposed via line 194. Moreover, the use of ethane having a higher heating value than nitrogen may result in a more efficient energy production of the flare that may be used for heating a subsequent or alternative process, *e.g.*, an olefins processing plant for producing olefins or polymerizing olefins.

[0067] The amount of the gas product via line 194 removed from the polymerization system 100 can range from about 0% v/v to about 10% v/v of the gas product via line 188, *e.g.*, about 0% v/v to about 3% v/v, about 3% v/v to about 6% v/v, about 6% v/v to about 9% v/v, or about 5% v/v to about 10% v/v. At times 100% v/v of the gas product in line 188 can be recycled via line 188 to the polymerization reactor 101. In another example, all or a portion of the gas product in line 188 can be vented to flare or an integrated olefins plant via line 194.

Finishing System

[0068] A gas-phase polymerization system of the present disclosure includes a polymer finishing system. Now referring to FIG. 2, a finishing system 199 is shown. A finishing system 199 receives a polymer product from the convey line 198. As shown in FIG. 2, the convey line can pass through one or more pieces of finishing equipment (*e.g.*, screener 202, feed bin 206, extruder 212, and collector 218). Conceptually, this entire path could be considered a single convey line, or, equivalently, a series of convey lines between each piece of equipment. As labeled in FIG. 2 for ease of distinction, multiple serial lines are shown as the convey line (that is, lines 198, 203, 207, and 217 as shown in FIG. 2 together make up the convey line for conveying product through the series of finishing equipment). Thus, in reference to FIG. 2, a specific line or segment of convey line may be referenced (*e.g.*, lines 198, 203, 207, or 217); and on the other hand, in discussion of various embodiments, a “convey line” or locations along a “convey line” may be referenced. It should be understood that any reference to “convey line” generally, unless expressly indicated otherwise, can refer to the pathway generally comprising lines 198 to 203 to 207 to 217 as shown in FIG. 2, tracing the pathway of polymer product through the various pieces of finishing equipment 202, 206, 212, 218, etc. Thus, a location along the “convey line” can mean, with reference to FIG. 2, a location along any of lines 198, 203, 207, or 217; although in some instances locations are specifically called out with reference to a particular line or segment (198, 203, 207, or 217, respectively) of the broader convey line. Moreover, a location referenced as “downstream” from another location or component means that such downstream location is further along the flow path as illustrated in FIG. 2; for example, the convey line 217 is downstream of line 207, which in turn is downstream of line

203, which in turn is downstream of line 198. Conversely, line 198 is “upstream” of line 203, etc.

[0069] Returning now to FIG. 2, the convey line 198 transfers the polymer product to a screener 202. The screener 202 may include a size separator suitable for one or more of sieving, sifting, filtering, and/or screening the polymer product. In at least one embodiment, the screener 202 may size separate a polymer product having polymer particles having a particle diameter of about 0.5 mm to about 10 mm, *e.g.*, about 0.5 mm to about 1 mm, about 1 mm to about 2 mm, about 2 mm to about 3 mm, about 3 mm to about 4 mm, about 4 mm to about 5 mm, about 5 mm to about 6 mm, about 6 mm to about 7 mm, about 7 mm to about 8 mm, about 8 mm to about 9 mm, or about 9 mm to about 10 mm.

[0070] In at least one embodiment, the finishing system 199 may include a first sensor 204 at a first location of the convey line 198, *e.g.*, at the screener 202 (as shown in FIG. 2), fluidly coupled by a line 205. A first sensor 204 may include any sensor suitable for detecting low molecular weight compounds, *e.g.*, a mass spectrometer such as a gas chromatography-mass spectrometer. The first sensor 204 can be integrated with the first location of the convey line 198). For example, the first sensor 204 can be external to the first location of the convey line and a portion of the fluid can be extracted from the convey line and analyzed by the first sensor 204 (either online, via a line such as line 205 as shown in FIG. 2; or offline, such as by sampling the fluid and analyzing it with the separate sensor). As another example, the first sensor 204 can be integrated in or with the screener 202, as shown in FIG. 2 (with fluid communication via line 205). Also, or instead, the first sensor 204 can be off-line to the screener 202. The first sensor 204 may analyze a first non-polymer component content, *e.g.*, a hydrocarbon content, of the polymer product at that location of the finishing system. For example, the first sensor 204 may determine a first hydrocarbon content of the first location to be about 30 ppmw to about 300 ppmw per pound of polymer product of line 203, *e.g.*, about 30 ppmw per pound of polymer product to about 50 ppmw per pound of polymer product, about 50 ppmw per pound of polymer product to about 70 ppmw per pound of polymer product, about 70 ppmw per pound of polymer product to about 80 ppmw per pound of polymer product, about 80 ppmw per pound of polymer product to about 100 ppmw per pound of polymer product, about 100 ppmw per pound of polymer product to about 120 ppmw per pound of polymer product, about 120 ppmw per pound of polymer product to about 140 ppmw per pound of polymer product, about 140 ppmw per pound of polymer product to about 160 ppmw per pound of polymer product, about 160 ppmw per pound of polymer product to about 180 ppmw per pound of polymer product, about 180 ppmw per pound of polymer product to about 200 ppmw per pound of polymer

product, about 200 ppmw per pound of polymer product to about 220 ppmw per pound of polymer product, about 220 ppmw per pound of polymer product to about 240 ppmw per pound of polymer product, about 240 ppmw per pound of polymer product to about 260 ppmw per pound of polymer product, about 260 ppmw per pound of polymer product to about 280 ppmw per pound of polymer product, or about 280 ppmw per pound of polymer product to about 300 ppmw per pound of polymer product.

[0071] The convey line 203 may convey the size separated polymer product to a feed bin 206. The feed bin 206 includes a container and/or tank. The feed bin 206 may have a volume of about 300 m³ to about 700 m³, *e.g.*, about 300 m³ to about 400 m³, about 400 m³ to about 600 m³, or about 600 m³ to about 700 m³. Optionally, the feed bin 206 may be configured to receive the separated polymer product from the convey line 203 from a topmost section of the feed bin 206. The separated polymer product may then fall to a lower section of the feed bin 206 by gravity.

[0072] In at least one embodiment, a first removal or recovery line 208 is disposed off the feed bin 206 along line 208. The first recovery line 208 may capture and remove from the system 199 one or more non-polymer components, *e.g.*, hydrocarbons such as VOCs, emitted from the separated polymer product. For example, the first recovery line may remove about 10 ppm to about 300 ppmw of non-polymer component(s) per pound of polymer product of line 203, *e.g.*, about 10 ppmw per pound of polymer product to about 50 ppmw per pound of polymer product, about 50 ppmw per pound of polymer product to about 70 ppmw per pound of polymer product, about 70 ppmw per pound of polymer product to about 80 ppmw per pound of polymer product, about 80 ppmw per pound of polymer product to about 100 ppmw per pound of polymer product, about 100 ppmw per pound of polymer product to about 120 ppmw per pound of polymer product, about 120 ppmw per pound of polymer product to about 140 ppmw per pound of polymer product, about 140 ppmw per pound of polymer product to about 160 ppmw per pound of polymer product, about 160 ppmw per pound of polymer product to about 180 ppmw per pound of polymer product, about 180 ppmw per pound of polymer product to about 200 ppmw per pound of polymer product, about 200 ppmw per pound of polymer product to about 220 ppmw per pound of polymer product, about 220 ppmw per pound of polymer product to about 240 ppmw per pound of polymer product, about 240 ppmw per pound of polymer product to about 260 ppmw per pound of polymer product, about 260 ppmw per pound of polymer product to about 280 ppmw per pound of polymer product, or about 280 ppmw per pound of polymer product to about 300 ppmw per pound of polymer product.

[0073] The removal effected by the first recovery line 208 may include conveying the one or more non-polymer components, *e.g.*, hydrocarbons such as VOCs, (optionally together with an oxidizing agent, such as air) to a control device (shown in FIG. 2 as thermal oxidizer 209); noting that in general a control device can include one or more of a flare, an oxidizer (*e.g.*, a
5 regenerative thermal oxidizer (RTO) or flameless thermal oxidizer (FTO), and/or boiler (not shown) where the one or more hydrocarbons are converted to a conversion product comprising CO₂ and H₂O. The conversion product, *e.g.*, CO₂ and H₂O, may then be released to atmosphere or flared. Without being bound by theory, by converting the one or more non-polymer components, *e.g.*, hydrocarbons such as VOCs, in the first recovery line 208, a reduction of
10 hydrocarbons being emitted to atmosphere may occur. It may be particularly advantageous to locate a control device (*e.g.*, thermal oxidizer 209) at or along this stage of the finishing system 199 (or, more generally, to locate a control device at a location of the finishing system 199 that is between the first sensor 204 and the second sensor 210 (discussed in more detail below)).

[0074] In at least one embodiment, a thermal oxidizer 209 may include a containment
15 vessel housing a matrix bed of inert, refractive media, such as ceramic balls or saddles, and a dip tube assembly at least partially positioned within the matrix bed. The dip tube assembly includes a fuel conduit for carrying fuel at least partially positioned within the matrix bed; an oxidizing agent conduit for carrying oxidizing agent at least partially positioned within the matrix bed and at least one mixing conduit at least partially positioned within the matrix bed
20 and configured to receive and combine fuel from the fuel conduit and oxidizing agent from the oxidizing agent conduit and to deliver the combination of fuel and oxidizing agent into the matrix bed of media. Examples of thermal oxidizers and/or boiler units are disclosed in US Patent Publication Nos. 2011/0283991, 2014/0283812, and 2017/0333839, incorporated herein by reference. In at least one embodiment, the thermal oxidizer 209 may include a flameless
25 thermal oxidizer or a regenerative thermal oxidizer. For example, the thermal oxidizer 209 may include a flameless thermal oxidizer. Without being bound by theory, a flameless thermal oxidizer may reduce operation costs as the flameless thermal oxidizer incorporates air to the thermal oxidizer as opposed to natural gas in the regenerative thermal oxidizer, in which air can be less expensive than natural gas.

[0075] When used in processes of the present disclosure, the thermal oxidizer 209 and/or
30 boiler feed typically comprises a primary fuel stream, a combustion air stream as the oxidizing agent and, in some cases, the stream from the first recovery line 208 (*e.g.*, as shown in FIG. 2). These streams all mix together in the dip tube to form the total combined-feed stream. The thermal oxidizer 209 and/or boiler (not shown) controls combustion air and/or non-polymer

components, *e.g.*, hydrocarbons such as VOCs, by adjusting one or more of a flow rate, concentration, or volume of fluid supplied to the thermal oxidizer 209 and/or boiler (not shown). Increased air lowers the heating value, and increased hydrocarbons increases the heating value. Generally, the thermal oxidizers are adjusted so that the total combined-feed heating value to the matrix bed of the thermal oxidizer unit is about 80% of the Lower Flammability Limit (LFL), which is defined as the lower end of the concentration range over which a flammable mixture of gas or vapor in air can be ignited at a given temperature and pressure. Accordingly, the thermal oxidizer may oxidize a flammable mixture of gas or vapor below the lower flammability limit.

[0076] Optionally, a stream from the feed bin 206 may be extracted and compressed in a recovery gas compressor 211 (as shown in FIG. 2) before being supplied to a thermal oxidizer 209 and/or boiler (not shown). A portion of the recovery gas compressor discharge may then be removed and recycled back to the suction side of the recovery gas compressor 211, optionally through a cooler (not shown in FIG. 2). By adjusting the recycle flow, for example, by means of a pressure controller, the compressor discharge can be maintained at a constant pressure despite pressure fluctuations in the feed to the compressor 211.

[0077] In at least one embodiment, the finishing system 199 may include a second sensor 210 at a second location of the convey line 207 *e.g.*, at a lower section of the feed bin 206, fluidly coupled via line 213. The second sensor 210 may analyze a second non-polymer component content, *e.g.*, hydrocarbon content, of the finishing system 199. For example, the second sensor 210 may determine a second hydrocarbon content at the second location to be about 7 ppmw per pound of polymer product to about 30 p ppmw per pound of polymer product of line 207, *e.g.*, about 7 ppmw per pound of polymer product to about 10 ppmw per pound of polymer product, about 10 ppmw per pound of polymer product to about 20 ppmw per pound of polymer product, or about 20 ppmw per pound of polymer product to about 30 ppmw per pound of polymer product. The second sensor 210 may include any sensor suitable for detecting low molecular weight compounds, *e.g.*, a mass spectrometer such as a gas chromatography-mass spectrometer. In at least one embodiment, the second sensor 210 is integrated in or with the convey line 207. In at least one embodiment, the second sensor 210 is external to the convey line 207 and a portion of the fluid is extracted from the convey line 207 and analyzed by the second sensor 210 (either online, via a line such as line 213 as shown in FIG. 2; or offline, such as by sampling the fluid and analyzing it with the separate sensor). In at least one embodiment, the second sensor 210 is off-line to the convey line 207.

[0078] The convey line 207 transfers the separated polymer product from the lower section of the feed bin 206 to an extruder 212. An extruder 212 can include a vertical pellet mill, a horizontal pellet mill, a briquetter, a dual roll briquetter, a rolling mill, and/or an extruder (*e.g.*, twin screw extruder)(which can be combined with an underwater pelletizer, which will extrude with pressure and without substantial (*e.g.*, complete) melting of the polymer through a capillary). As the polymer product flows through a capillary, it can be cut or broken to a desired shape. Such processes are designed to compact the product without fully melting the solid. Briquetting machines may also be used to compact the product into a shape directly without flow through a capillary. In some cases, the outside surface of a pellet or briquette may be subjected to sintering to increase the strength and reduce the brittleness of the pellet/briquette. A briquette can be larger than a pellet. In some embodiments, a briquette or pellet of the present disclosure can be about 4 mm diameter by 4 mm length +/- 30%. In some embodiments, a pellet has a diameter of about 2.6 mm to about 4.5 mm. In some embodiments, a pellet has a length of about 2 mm to about 8 mm.

[0079] In at least one embodiment, the extruder 212 may operate at a temperature of less than about 110 °C, such as about 70 °C to about 110 °C, such as about 80 °C to about 100 °C. In at least one embodiment, the extruder 212 may operate at a pressure of up to about 25,000 pounds per square inch (psi), *e.g.*, about 0 psi to about 100 psi, about 100 psi to about 200 psi, about 200 psi to about 300 psi, about 300 psi to about 400 psi, about 400 psi to about 500 psi, about 500 psi to about 1,000 psi, about 1,000 psi to about 5,000 psi, about 5,000 psi to about 10,000 psi, about 10,000 psi to about 15,000 psi, about 15,000 psi to about 20,000 psi, or about 20,000 psi to about 25,000 psi.

[0080] In at least one embodiment, a second removal or recovery line 215 is disposed off of feed line 207 to extruder 212 (not shown) or it may be disposed along and/or fluidly coupled to the extruder 212 (as shown in FIG. 2). The second recovery line 215 may capture and remove from the system one or more non-polymer components, *e.g.*, hydrocarbons, emitted from the separated product. For example, the second recovery line 215 may remove about 0.1 ppmw of non-polymer component(s) per pound of polymer product to about 20 ppmw per pound of polymer product of line 215, *e.g.*, about 0.1 ppmw per pound of polymer product to about 1 ppmw per pound of polymer product, about 1 ppmw per pound of polymer product to about 5 ppmw per pound of polymer product, about 5 ppmw per pound of polymer product to about 10 ppmw per pound of polymer product, about 10 ppmw per pound of polymer product to about 15 ppmw per pound of polymer product, or about 15 ppmw per pound of polymer product to about 20 ppmw per pound of polymer product. The second recovery line 215 may convey the

one or more hydrocarbons (optionally together with an oxidizing agent, such as air) to a control system, such as a flare, a thermal oxidizer (e.g., flameless thermal oxidizer (FTO) or regenerative thermal oxidizer (RTO)), and/or boiler where the one or more hydrocarbons are converted to CO₂ and H₂O, as described above. For instance, removal or recovery line 215 is shown feeding into a control system (thermal oxidizer 214) in FIG. 2. Without being bound by theory, by converting the one or more hydrocarbons in the second recovery line 215 a reduction of hydrocarbons being emitted to atmosphere may occur. more particularly, the second recovery line 215 may convey the one or more hydrocarbons (optionally together with an oxidizing agent, such as air) to a thermal oxidizer 214 and/or boiler (not shown) where the one or more hydrocarbons are converted to CO₂ and H₂O, as described above. Without being bound by theory, by converting the one or more hydrocarbons in the second recovery line 215, a reduction and/or elimination of hydrocarbons being emitted to atmosphere may occur.

[0081] In at least one embodiment, the finishing system 199 may include a third sensor 216 at a third location of the convey line 217 *e.g.*, at the outlet of the extruder 212, or along the convey line 217 exiting the extruder (as shown in FIG. 2, fluidly coupled via line 219). The third sensor 216 may analyze a third non-polymer component content, *e.g.*, hydrocarbon content, of the finishing system 199 at line 217. For example, the third sensor 216 may determine a third hydrocarbon content at the third location to be about 5 ppmw per pound of polymer product to about 30 ppmw per pound of polymer product, *e.g.*, about 5 ppmw per pound of polymer product to about 10 ppmw per pound of polymer product, about 10 ppmw per pound of polymer product to about 20 ppmw per pound of polymer product, or about 20 ppmw per pound of polymer product to about 30 ppmw per pound of polymer product.

[0082] The third sensor 216 may include any sensor suitable for detecting low molecular weight compounds, *e.g.*, a mass spectrometer such as a gas chromatography-mass spectrometer. In at least one embodiment, the third sensor 216 is integrated with the extruder 212. In at least one embodiment, the third sensor 216 is external to the extruder 212 and a portion of the fluid is extracted from the extruder 212 and analyzed by the third sensor 216 (either online, via a line such as line 219 as shown in FIG. 2; or offline, such as by sampling the fluid and analyzing it with the separate sensor). In at least one embodiment, the third sensor 216 is integrated in the extruder 212. In at least one embodiment, the third sensor 216 is off-line to the extruder 212. Alternatively, or in addition, the third sensor 216 can be integrated into the convey line 217 exiting the extruder; or can be external to the convey line 217 but fluidly coupled (*e.g.*, via a line 219 as is shown in FIG. 2); and/or the third sensor 216 can be offline to the extruder 212 and convey line 217.

[0083] The convey line 217 transfers the extruded polymer product to a collector 218. The collector 218 may include a container and/or tank suitable for holding a volume of the extruded polymer pellets/briquettes. In at least one embodiment, the collector 218 may collect polymer product having a bulk density of about 500 kg/m³ to about 600 kg/m³, *e.g.*, about 500 kg/m³ to about 520 kg/m³, about 520 kg/m³ to about 540 kg/m³, about 540 kg/m³ to about 560 kg/m³, about 560 kg/m³ to about 580 kg/m³, or about 580 kg/m³ to about 600 kg/m³. In at least one embodiment, the collector 218 may collect polymer product having a particle diameter of about 0.5 mm to about 10 mm, *e.g.*, about 0.5 mm to about 1 mm, about 1 mm to about 2 mm, about 2 mm to about 3 mm, about 3 mm to about 4 mm, about 4 mm to about 5 mm, about 5 mm to about 6 mm, about 6 mm to about 7 mm, about 7 mm to about 8 mm, about 8 mm to about 9 mm, or about 9 mm to about 10 mm. In at least one embodiment, the collector 218 may be configured to receive the extruded polymer product where a fourth sensor 220, fluidly coupled via line 222, at a fourth location, *e.g.*, the collector 218, may analyze the extruded polymer product for a fourth non-polymer component content, *e.g.*, a hydrocarbon content. The fourth sensor 220 may analyze a fourth hydrocarbon content of the finishing system 199. For example, the fourth sensor 220 may determine a fourth hydrocarbon content at the fourth location to be about 0 ppmw per pound of polymer product to about 20 ppmw per pound of polymer product of line 217, *e.g.*, about 0 ppmw per pound of polymer product to about 5 ppmw per pound of polymer product, about 5 ppmw per pound of polymer product to about 10 ppmw per pound of polymer product, about 10 ppmw per pound of polymer product to about 15 ppmw per pound of polymer product, or about 15 ppmw per pound of polymer product to about 20 ppmw per pound of polymer product. The fourth sensor 220 may include any sensor suitable for detecting low molecular weight compounds, *e.g.*, a mass spectrometer such as a gas chromatography-mass spectrometer. In at least one embodiment, the fourth sensor 220 is integrated with the collector 218, or is in fluid communication with it (*e.g.*, via line 222 as shown in FIG. 2). As another example, the fourth sensor 220 can be external to the collector 218 and a portion of the fluid can be extracted from the collector 218 and analyzed by the fourth sensor 220 (either online, via a line such as line 222; or offline, such as by sampling the fluid and analyzing it with the separate sensor). In at least one embodiment, the fourth sensor 220 is integrated in the collector 218. In at least one embodiment, the fourth sensor 220 is off-line to the collector 218.

[0084] In at least one embodiment, a third recovery line 224 is disposed on the collector 218. The third recovery line 224 may capture and remove from the system one or more non-polymer components, *e.g.*, hydrocarbons, emitted from the extruded product. For example, the third recovery line 224 may remove about 0.1 ppmw of non-polymer component(s) per pound

of polymer product to about 20 ppmw per pound of polymer product of line 217, *e.g.*, about 0.1 ppmw per pound of polymer product to about 1 ppmw per pound of polymer product, about 1 ppmw per pound of polymer product to about 5 ppmw per pound of polymer product, about 5 ppmw per pound of polymer product to about 10 ppmw per pound of polymer product, about 10 ppmw per pound of polymer product to about 15 ppmw per pound of polymer product, or about 15 ppmw per pound of polymer product to about 20 ppmw per pound of polymer product. The third recovery line 224 may convey the one or more hydrocarbons (optionally together with an oxidizing agent, such as air) to a thermal oxidizer 226 and/or boiler (not shown) where the one or more hydrocarbons are converted to CO₂ and H₂O, as described above. Without being bound by theory, by converting the one or more hydrocarbons in the third recovery line 224 a reduction and/or elimination of hydrocarbons being emitted to atmosphere may occur.

[0085] While exemplary locations of the first sensor 204, the second sensor 210, the third sensor 216, and the fourth sensor 220 have been shown, any number of sensors may be located in any position along the finishing system 200, as described herein.

15 Catalyst Systems

[0086] The term “catalyst system” includes at least one “catalyst component,” at least one “activator,” and an optional support material. The catalyst system can also include other components, such as the catalyst component and/or activator alone or in combination. The catalyst system can include any number of catalyst components in any combination as described, as well as any activator in any combination as described.

[0087] The term “catalyst component” or “catalyst compound” includes any compound that, once appropriately activated, is capable of catalyzing the polymerization or oligomerization of olefins. The catalyst component may include at least one Group 3 to Group 12 atom and optionally at least one leaving group bound thereto. The term “leaving group” refers to one or more chemical moieties bound to the metal center of the catalyst component that can be abstracted from the catalyst component by an activator, thereby producing the species active towards olefin polymerization or oligomerization. Suitable activators are described in detail below.

[0088] As used herein, in reference to Periodic Table “Groups” of Elements, the “new” numbering scheme for the Periodic Table Groups are used as in the CRC Handbook of Chemistry and Physics (David R. Lide, ed., CRC Press 81st ed. 2000).

[0089] Suitable metallocene catalyst compounds can include metallocenes described in U.S. Pat. Nos.: 7,179,876; 7,169,864; 7,157,531; 7,129,302; 6,995,109; 6,958,306; 6,884,748; 6,689,847; 5,026,798; 5,703,187; 5,747,406; 6,069,213; 7,244,795; 7,579,415; U.S. Patent

Application Publication No. 2007/0055028; and WO Publications WO 97/22635; WO 00/699/22; WO 01/30860; WO 01/30861; WO 02/46246; WO 02/50088; WO 04/022230; WO 04/026921; and WO 06/019494.

[0090] As used herein, the terms "activator" refers to any compound or combination of compounds, supported or unsupported, which can activate a catalyst compound or component, such as by creating a cationic species of the catalyst component. For example, this can include the abstraction of at least one leaving group (the "X" group in the single site catalyst compounds described herein) from the metal center of the catalyst compound/component. Activators can include Lewis acids such as cyclic or oligomeric poly(hydrocarbylaluminum oxides) and so called non-coordinating activators ("NCA") (alternately, "ionizing activators" or "stoichiometric activators"), or any other compound that can convert a neutral metallocene catalyst component to a metallocene cation that is active with respect to olefin polymerization. Illustrative Lewis acids include aluminoxane (e.g., methylaluminoxane "MAO"), modified aluminoxane (e.g., modified methylaluminoxane "MMAO" and/or tetraisobutylaluminoxane "TIBAO"), and alkylaluminum compounds. Ionizing activators (neutral or ionic) such as tri (n-butyl)ammonium tetrakis(pentafluorophenyl)boron may be also be used. Further, a tris(perfluorophenyl) boron metalloid precursor may be used. Any of those activators/precursors can be used alone or in combination with the others. There are a variety of methods for preparing aluminoxane and modified aluminoxanes known in the art.

[0091] The catalyst compositions can include a support material or carrier. As used herein, the terms "support" and "carrier" are used interchangeably and are any support material, including a porous support material, for example, talc, inorganic oxides, and inorganic chlorides. The catalyst component(s) and/or activator(s) can be deposited on, contacted with, vaporized with, bonded to, or incorporated within, adsorbed or absorbed in, or on, one or more supports or carriers. Other support materials can include resinous support materials such as polystyrene, functionalized or crosslinked organic supports, such as polystyrene divinyl benzene polyolefins or polymeric compounds, zeolites, clays, or any other organic or inorganic support material and the like, or mixtures thereof.

[0092] Inorganic oxides supports can include Group 2, 3, 4, 5, 13 or 14 metal oxides. Exemplary supports include silica, which may or may not be dehydrated, fumed silica, alumina, silica-alumina and mixtures thereof. Other useful supports include magnesia, titania, zirconia, magnesium chloride, montmorillonite, phyllosilicate, zeolites, talc, clays, and the like. Also, combinations of these support materials may be used, for example, silica-chromium, silica-

alumina, silica-titania and the like. Additional support materials may include those porous acrylic polymers described in EP 0 767 184, which is incorporated herein by reference.

[0093] The polymer product(s) produced in the reactor can be or include any type of polymer or polymeric material. For example, the polymer product can include homopolymers of olefins (e.g., homopolymers of ethylene), and/or copolymers, terpolymers, and the like of olefins, particularly ethylene, and at least one other olefin. Illustrative polymers can include polyolefins, polyamides, polyesters, polycarbonates, polysulfones, polyacetals, polylactones, acrylonitrile-butadiene-styrene polymers, polyphenylene oxide, polyphenylene sulfide, styrene-acrylonitrile polymers, styrene maleic anhydride, polyimides, aromatic polyketones, or mixtures of two or more of the above. Suitable polyolefins can include polymers comprising one or more linear, branched or cyclic C₂ to C₄₀ olefins, such as polymers comprising propylene copolymerized with one or more C₃ to C₄₀ olefins, such as a C₃ to C₂₀ alpha olefin, more such as C₃ to C₁₀ alpha-olefins. Exemplary polyolefins include polymers comprising ethylene including ethylene copolymerized with a C₃ to C₄₀ olefin, such as a C₃ to C₂₀ alpha olefin, more such as propylene and or butene.

Polymer Products

[0094] Example polymers include homopolymers or copolymers of C₂ to C₄₀ olefins, such as C₂ to C₂₀ olefins, such as a copolymer of an alpha-olefin and another olefin or alpha-olefin (ethylene is defined to be an alpha-olefin for purposes of this disclosure). The polymers may be or include homopolyethylene, homopolypropylene, propylene copolymerized with ethylene and or butene, ethylene copolymerized with one or more of propylene, butene or hexene, and optional dienes. Examples include thermoplastic polymers such as ultra low density polyethylene, very low density polyethylene ("VLDPE"), linear low density polyethylene ("LLDPE"), low density polyethylene ("LDPE"), medium density polyethylene ("MDPE"), high density polyethylene ("HDPE"), polypropylene, isotactic polypropylene, highly isotactic polypropylene, syndiotactic polypropylene, random copolymer of propylene and ethylene and/or butene and/or hexene, elastomers such as ethylene propylene rubber, ethylene propylene diene monomer rubber, neoprene, and blends of thermoplastic polymers and elastomers, such as for example, thermoplastic elastomers and rubber toughened plastics.

[0095] Polyethylene polymers produced in a gas phase polymerization process are characterized by a number of parameters, including density, melt index (I₂), high load melt index (I₂₁ or HLMI), melt index ratio (MIR), number average molecular weight (M_n), weight average molecular weight (M_w), Z-average molecular weight (M_z), molecular weight distribution (M_w/M_n or MWD), the ratio of the Z-average molecular weight to the weight

average molecular weight (M_z/M_w), composition distribution melt index, and branching index (g'). These parameters are related to physical characteristics of polymer chains, including lengths of polymer chains, distribution of lengths of polymer chains, comonomer distribution among and along polymer chains, and length and number of branches on polymer chains.

5 These physical characteristics of polymer chains lead to different mechanical properties that make different polyethylene polymers suitable for a broad range of end-use applications.

[0096] Polymerization conditions in a fluidized bed in a polymerization reaction zone can be controlled both to produce polyethylene polymers having a desired combination of parameters and to maintain the stability of polymerization reaction in a gas phase reactor. Such
10 polymerization conditions include reactor temperature, reactor pressure, ethylene monomer feed rate, comonomer type and feed rate, catalyst type and feed rate, comonomer-to-ethylene ratio, rate of addition of hydrogen, an amount of one or more induced condensing agents, an amount of one or more continuity additives, and delta melt initiation temperature (dMIT; see U.S. Pat. No. 7,683,140, the contents of which are fully incorporated by reference herein).

15 [0097] Polyethylene producers typically identify each polyethylene polymer having a particular set of properties by a grade name and/or number. Density and melt index (I_2) are generally key parameters associated with each polyethylene polymer grade. For the producer, each such polyethylene polymer grade is associated with a particular set of polymerization conditions.

20 EXAMPLES

Example 1

[0098] A convey line was analyzed in a gas-phase polymerization system to determine an amount of hydrocarbons at a first location, third location, and fourth location. A first and second sample (example 1-1 and 1-2, respectively) was taken from the convey line and placed in a
25 sealed vial, where the conditions associated with the first sample included a steam purge bin operated at 80% of the predetermined set point, and the second sample conditions included a steam purge bin operated at 110%-125% of the predetermined set point. The sealed vial was then weighed before and after being connected to a gas chromatograph. The oven of the gas chromatograph heated the sample vial, resulting in the vaporization of dissolved components
30 which were then directed to the gas chromatograph. The difference in the sample vial mass before and after heating was determined and a weight percent of the volatilized components in the sample was calculated. The hydrocarbon concentrations at the first location (*e.g.*, the intersection of line 205 and the screener 202, corresponding to sensor 204 as depicted in FIG. 2), third location (*e.g.*, the extruder 212 and line 215, corresponding to sensor 214 as depicted

in FIG. 2), and fourth location (*e.g.*, the intersection of the collector 218 and line 222, corresponding to sensor 220 as depicted in FIG. 2) reduced along each subsequent location, as shown below in Table 1. This indicated that under either operating condition, the system experienced a loss of VOCs to atmosphere when progressing gases through the convey line.

5 **Table 1.**

Example	First Location	Third Location	Fourth Location	Third location – Fourth Location
1-1	47 ppm	26 ppm	17 ppm	9 ppm
1-2	39 ppm	19 ppm	11 ppm	8 ppm

Example 2

[0099] A convey line was analyzed in a gas-phase polymerization system to determine an amount of hydrocarbons at a first location, second location, third location, and fourth location.

10 Results are shown below in Table 2. The average percent loss (% Loss) is relative to the previous measurement.

Table 2.

	First Location	Second Location	Third Location	Fourth Location	Third location – Fourth Location
AVERAGE (% Loss)	N/A	35%	15%	25%	
Convey Line	41 ppm	26.7 ppm	20.5 ppm	10.25 ppm	10.25 ppm

[0100] The hydrocarbon concentrations at the first location (*e.g.*, the intersection of line 15 205 and the screener 202, corresponding with sensor 204 as shown in FIG. 2), second location, (*e.g.*, intersection of lines 207 and 213, corresponding with sensor 210 as shown in FIG. 2), third location (*e.g.*, the extruder 212 and line 215, corresponding with sensor 214 as shown in FIG. 2), and fourth location (*e.g.*, the intersection of the collector 218 and line 222, corresponding with sensor 220 as shown in FIG. 2) reduced along each subsequent location, which indicated losses of VOCs to atmosphere when progressing through the convey line, just 20 as in Example 1. Here, we also see that the biggest loss occurred between the first location and the second location, indicating that of the monitored locations, this first location (*e.g.*, the most upstream along the convey line) is the most effective location for offtake of VOCs for VOC control (*e.g.*, flare, recycle, or the like) so as to achieve the greatest reduction of VOC venting 25 with a single offtake line.

Example 3

[0101] A convey line was analyzed in a gas-phase polymerization system to determine an amount of hydrocarbons at a first location (*e.g.*, the intersection of line 205 and the screener 202, corresponding with sensor 204 as shown in FIG. 2), second location, (*e.g.*, intersection of lines 207 and 213, corresponding with sensor 210 as shown in FIG. 2), third location (*e.g.*, the extruder 212 and line 215, corresponding with sensor 214 as shown in FIG. 2), and fourth location (*e.g.*, the intersection of the collector 218 and line 222 corresponding with sensor 220 as shown in FIG. 2). Additionally, a hydrocarbon content in the first location (*e.g.*, the intersection of line 205 and the screener 202), second location, (*e.g.*, intersection of lines 207 and 213), third location (*e.g.*, the extruder 212 and line 215), and fourth location (*e.g.*, the intersection of the collector 218 and line 222) was determined when using a first recovery line (*e.g.*, line 208), second recovery line (*e.g.*, line 215), and/or third recovery line (*e.g.*, line 224) to remove hydrocarbons, *e.g.*, VOCs, from the system. Results are shown below in Table 3. Considering the mass balance, Table 3's results at each of the first, second, third, and fourth locations, as described above, show that hydrocarbon is leaving the system through between each respective sensor location, thereby proving the value of routing one or more recovery lines to a control system such as a flameless thermal oxidizer (FTO) or regenerative thermal oxidizer (RTO). Indeed, these are the systems deployed as indicated in Table 3, with the differences between each location indicating the level of hydrocarbon (*e.g.*, VOC) being destroyed in the oxidizers.

Table 3.

Grade	First Location	Second Location	Third Location	Fourth Location	Third location – Fourth Location
Sample 1 (flameless thermal oxidizer)	119.5	8.2	6.71	0	6.71
Sample 2 (regenerative thermal oxidizer)	Not Measured	10.6	10.99	2.65	8.36
Sample 3 (flameless thermal oxidizer)	123.5	8.99	8.15	0	8.15
Sample 4 (regenerative thermal oxidizer)	Not Measured	15.8	11.4	2.64	8.76

[0102] Overall, a reduction and/or elimination of volatile organic compounds being emitted to atmosphere may occur through the use of one or more thermal oxidizers. The finishing systems provided can prevent one or more hydrocarbons, *e.g.*, volatile organic compounds, from being emitted to atmosphere by recovering the hydrocarbons in the convey line and transmitting them to a combustion and/or thermal oxidation system. The combustion and/or thermal oxidation system may convert about 99.99% to about 99.9999% of the hydrocarbons to CO₂ and H₂O, as compared to conventional finishing systems that allow the VOCs to be emitted to atmosphere.

EMBODIMENTS

[0103] The present disclosure provides, among others, the following embodiments, each of which can be considered as optionally including any alternate embodiments:

[0104] E1. A method, including supplying a polymer product of a polymerization reactor to a purge bin, in which the polymer product includes one or more non-polymer components; transferring the polymer product to a screener; determining a first non-polymer component content at a first location using a first sensor, in which the first location is disposed on a first convey line downstream of the screener or is disposed on the screener; transferring the polymer product to a feed bin; removing a non-polymer component using a first recovery line disposed on or near the feed bin; and determining a second non-polymer component content at a second location using a second sensor, in which the second location is disposed on a second convey line downstream of the feed bin and upstream of an extruder.

[0105] E2. The method of embodiment E1, in which the one or more non-polymer components are selected from the group consisting of unreacted monomers, unreacted comonomers, hydrogenated monomers, hydrogenated comonomers, impurities, catalytic components, and combinations thereof.

[0106] E3. The method of embodiment E1, in which the one or more non-polymer components includes a hydrocarbon.

[0107] E4. The method of any one of embodiments E1-E4, further including producing an extruded polymer product by transferring the polymer product to the extruder from the feed bin.

[0108] E5. The method of embodiment E4, further including determining a third non-polymer component content at a third location using a third sensor.

[0109] E6. The method of embodiment E5, in which the third location is disposed on a third convey line downstream of the extruder and upstream of a collector.

[0110] E7. The method of embodiment E6, further including determining a fourth non-polymer component content at a fourth location using a fourth sensor, in which the fourth location is disposed on the collector.

[0111] E8. The method of embodiment E7, in which the second non-polymer component content is lower than the first non-polymer component content; the third non-polymer component content is lower than the second non-polymer component content; and the fourth non-polymer component content is lower than the third non-polymer component content.

[0112] E9. The method of any one of embodiments, E1-E8, in which the first recovery line directs the non-polymer components to recycle or combustion.

[0113] E10. The method of embodiment E9, in which the first recovery line directs the non-polymer components to combustion.

[0114] E11. The method of embodiment E10, further including combusting the non-polymer components using a thermal oxidizer including a flameless thermal oxidizer or a regenerative thermal oxidizer.

[0115] E12. The method of embodiment E11, in which the thermal oxidizer includes a flameless thermal oxidizer.

[0116] E13. The method of any one of embodiments, E1-E12, further including removing a non-polymer component using a second recovery line disposed on or near the extruder.

[0117] E14. The method of embodiment E13, further including removing a non-polymer component using a third recovery line disposed on or near the collector.

[0118] E15. The method of any one of embodiments E1-E15, in which the polymerization reactor is a gas-phase polymerization reactor.

[0119] E16. A finishing system of a polymerization reactor, including a first convey line fluidly coupled to an inlet of a screener; a second convey line fluidly coupled to an outlet of the screener and an inlet of a feed bin; a third convey line fluidly coupled to an outlet of the feed bin and an inlet of an extruder; a fourth convey line fluidly coupled to an outlet of the extruder and an inlet of a collector, in which a first recovery line is fluidly coupled to the feed bin, extruder, or collector; and a first sensor fluidly coupled to a first location, second location, or third location along the first convey line, the second convey line, or the third convey line.

[0120] E17. The finishing system of embodiment E16, in which the first recovery line is fluidly coupled to the feed bin.

[0121] E18. The finishing system of embodiment E16, in which the first recovery line is fluidly coupled to the extruder.

[0122] E19. The finishing system of embodiment E16, in which the first recovery line is fluidly coupled to the collector.

[0123] E20. The finishing system of any one of embodiments E16-E19, in which the first sensor is disposed at the first location along the first convey line.

5 [0124] E21. The finishing system of embodiment E20, further including a second sensor disposed at the second location along the second convey line.

[0125] E22. The finishing system of embodiment E21, further including a third sensor disposed at the third location along the third convey line.

10 [0126] E23. The finishing system of embodiment E22, further including a fourth sensor disposed at the fourth location along the fourth convey line.

[0127] Certain embodiments and features have been described using a set of numerical upper limits and a set of numerical lower limits. It should be appreciated that ranges including the combination of any two values, e.g., the combination of any lower value with any upper value, the combination of any two lower values, and/or the combination of any two upper values are contemplated unless otherwise indicated. Certain lower limits, upper limits and ranges appear in one or more claims below. All numerical values are "about" or "approximately" the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

15 [0128] All documents and references cited herein, including testing procedures, publications, patents, journal articles, etc. are herein fully incorporated by reference for all jurisdictions in which such incorporation is permitted and to the extent such description is consistent with the disclosure.

[0129] Likewise, whenever a composition, an element or a group of elements is preceded with the transitional phrase "comprising", it is understood that we also contemplate the same composition or group of elements with transitional phrases "consisting essentially of," "consisting of", "selected from the group of consisting of," or "is" preceding the recitation of the composition, element, or elements and vice versa. The phrases, unless otherwise specified, "consists essentially of" and "consisting essentially of" do not exclude the presence of other steps, elements, or materials, whether or not, specifically mentioned in this specification, so long as such steps, elements, or materials, do not affect the basic and novel characteristics of the claimed disclosure, additionally, the phrases do not exclude impurities and variances normally associated with the elements and materials used.

25 [0130] While the claimed disclosure is described with respect to a number of embodiments and examples, those skilled in the art, having benefit of this disclosure, will appreciate that

other embodiments can be devised which do not depart from the scope and spirit of the disclosure.

CLAIMS

1. A method, comprising:
 - supplying a polymer product of a polymerization reactor to a purge bin, wherein the polymer product comprises one or more non-polymer components;
 - transferring the polymer product to a screener;
 - determining a first non-polymer component content at a first location using a first sensor, wherein the first location is downstream of the screener or is disposed on the screener;
 - transferring the polymer product to a feed bin;
 - removing a non-polymer component using a first recovery line disposed on or near the feed bin; and
 - determining a second non-polymer component content at a second location downstream of the first location using a second sensor, wherein the second non-polymer component content is lower than the first non-polymer component content.
2. The method of claim 1, wherein the one or more non-polymer components are selected from the group consisting of unreacted monomers, unreacted comonomers, hydrogenated monomers, hydrogenated comonomers, impurities, catalytic components, and combinations thereof.
3. The method of claim 1, wherein the one or more non-polymer components comprises one or more volatile organic compounds (VOCs).
4. The method of claim 1 or any one of claims 2-3, wherein the second location is downstream of the feed bin and upstream of an extruder; and wherein the method further comprises producing an extruded polymer product by transferring the polymer product to the extruder from the feed bin.
5. The method of claim 1 or any one of claims 2-4, wherein the first location is downstream of the screener, and further wherein the first and second locations are each along a convey line traversing the screener and feed bin, and through which the polymer product is flowed.
6. The method of claim 4, further comprising determining a third non-polymer component content at a third location downstream of the second location, using a third sensor, wherein the third location is either disposed on the extruder or is downstream of the extruder and upstream of a collector.
7. The method of claim 6, further comprising removing a portion of the second non-polymer component content using a second recovery line downstream of the second location and upstream of

the third location, further wherein the third non-polymer component content is less than the second non-polymer component content.

8. The method of claim 6 or claim 7, further comprising determining a fourth non-polymer component content at a fourth location downstream of the third location using a fourth sensor.

9. The method of claim 8, further comprising removing a portion of the third non-polymer component content using a third recovery line downstream of the third location and upstream of the fourth location, further wherein the fourth non-polymer component content is less than the third non-polymer component content.

10. The method of claim 8 or claim 9, wherein each of the first, second, third, and fourth locations is along a convey line through which polymer product is flowed, and which traverses the screener, feed bin, extruder, and collector.

11. The method of claim 7, wherein the second recovery line is disposed on or near the extruder.

12. The method of claim 9, wherein the third recovery line is disposed on or near the collector.

13. The method of claim 1, wherein the first recovery line directs the non-polymer components to recycle or combustion.

14. The method of claim 13, wherein the first recovery line directs the non-polymer components to combustion, optionally wherein combustion is carried out using a thermal oxidizer.

15. The method of claim 14, wherein the thermal oxidizer comprises a flameless thermal oxidizer.

16. The method of claim 8, wherein the second recovery line and/or the third recovery line directs the non-polymer components to combustion, optionally wherein combustion is carried out using a thermal oxidizer.

17. The method of claim 16, wherein the thermal oxidizer comprises a flameless thermal oxidizer.

18. The method of claim 1 or any one of claims 2-17, wherein the polymerization reactor is a gas-phase polymerization reactor.

19. A method comprising:

supplying a polymer product of a polymerization reactor to a finishing system comprising a convey line that traverses one or more pieces of finishing equipment;

wherein the one or more pieces of finishing equipment comprise one or more of a screener, a feed bin, an extruder, and a collector;

further wherein the polymer product comprises one or more non-polymer components;

flowing the polymer product through the convey line such that it passes through the one or more pieces of finishing equipment;

removing at least a portion of the non-polymer components from the convey line via one or more removal lines, wherein removing the portion of the non-polymer components comprises combusting the portion of the non-polymer components using a flare, a boiler, and/or a thermal oxidizer.

20. The method of claim 19, wherein the one or more non-polymer components comprise one or more volatile organic compounds (VOCs) such that the combusting forms a combustion product comprising CO₂ and H₂O; and further wherein the one or more removal lines comprise at least one of the following:

a first removal line disposed on the screener or along the convey line near the screener;

a second removal line disposed on the extruder or along the convey line near the extruder;

and

a third removal line disposed on the collector or along the convey line near the collector.

21. The method of claim 20, wherein the one or more removal lines comprise the first removal line, the second removal line, and the third removal line, and further wherein the second removal line is disposed downstream of the first removal line, and the third removal line is disposed downstream of the second removal line.

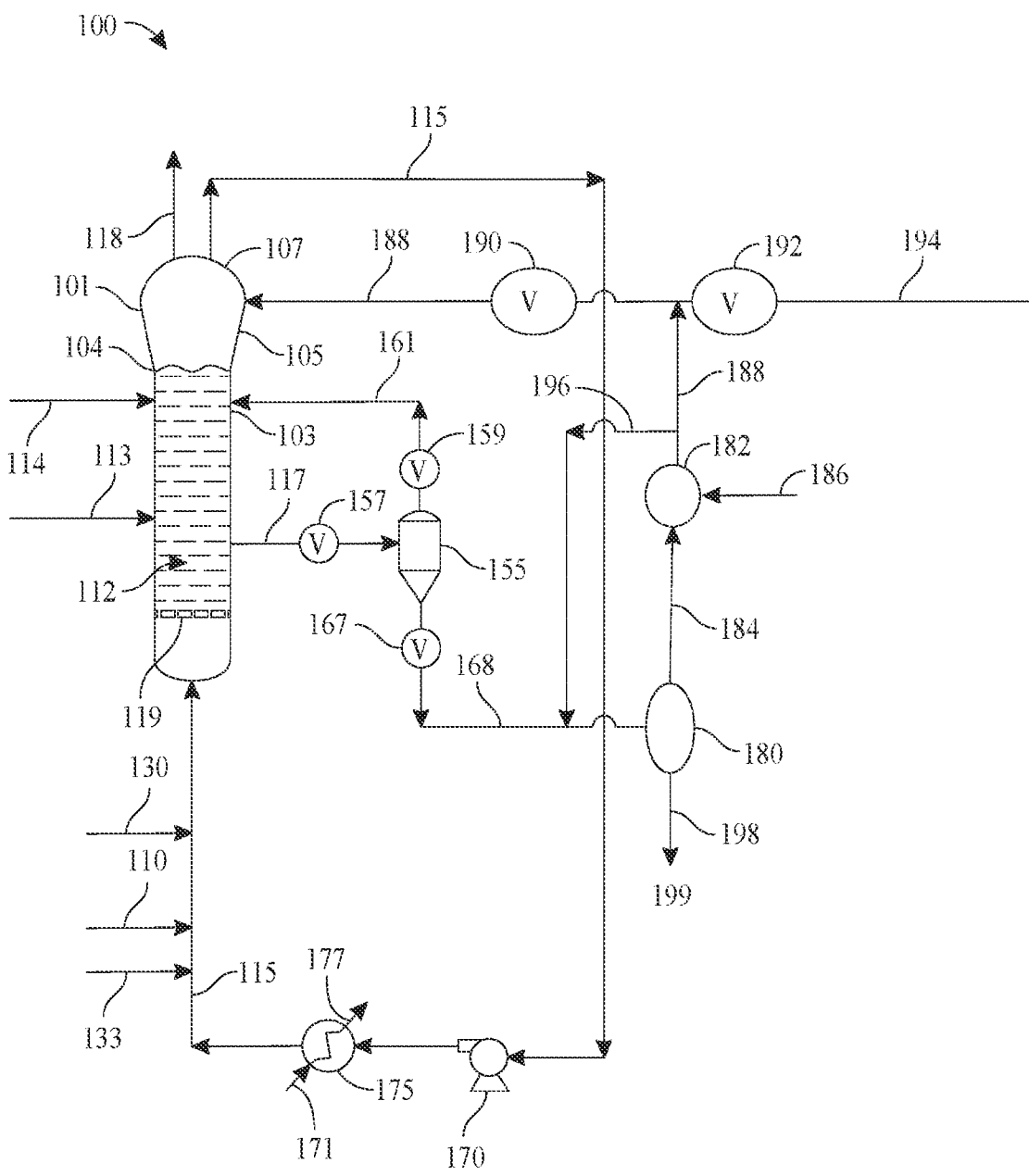


FIG. 1

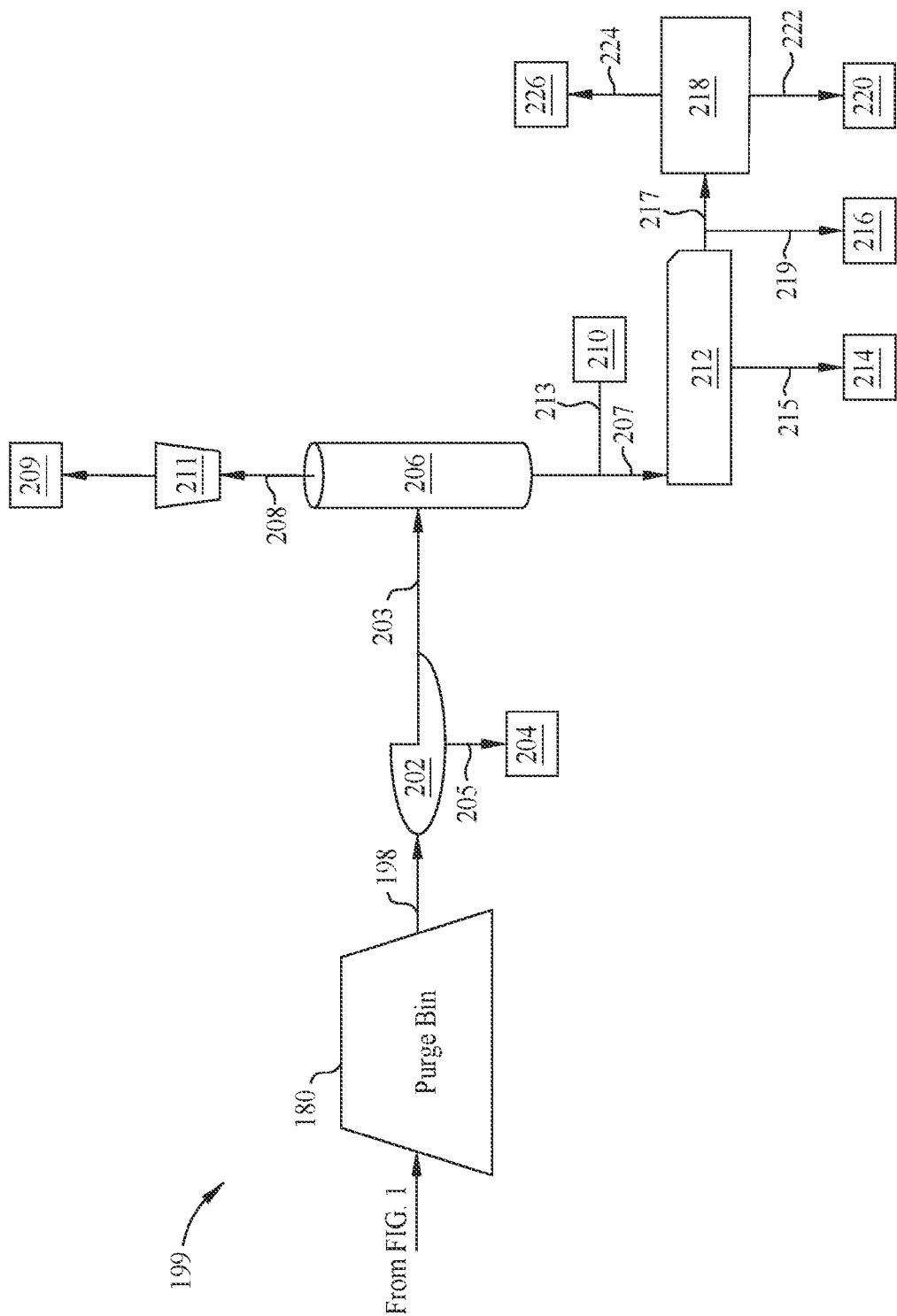


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2024/057281

A. CLASSIFICATION OF SUBJECT MATTER INV. C08F6/00 ADD.		
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) C08F B29C C08L		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 11 021 549 B2 (CHEVRON PHILLIPS CHEMICAL CO LP [US]) 1 June 2021 (2021-06-01) abstract column 12, lines 27-29 column 14, lines 57-63 column 16, lines 51-55 claim 1 figure 3	1 - 21
Y	WO 2018/204026 A1 (EXXONMOBIL CHEMICAL PATENTS INC [US]) 8 November 2018 (2018-11-08) abstract claim 1 figure 1	1 - 18
	- / - -	
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "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 13 March 2025		Date of mailing of the international search report 21/03/2025
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Koning, Erik

INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	RU 2 655 159 C2 (SHEVRON FILLIPS KEMIKAL KOMPANI ELPI [US]) 24 May 2018 (2018-05-24) paragraph [0095] -----	19 - 21
T	CN 219 588 962 U (DURR PAINTING SYSTEMS ENG SHANGHAI CO LTD) 25 August 2023 (2023-08-25) abstract -----	15, 17

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2024/057281

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