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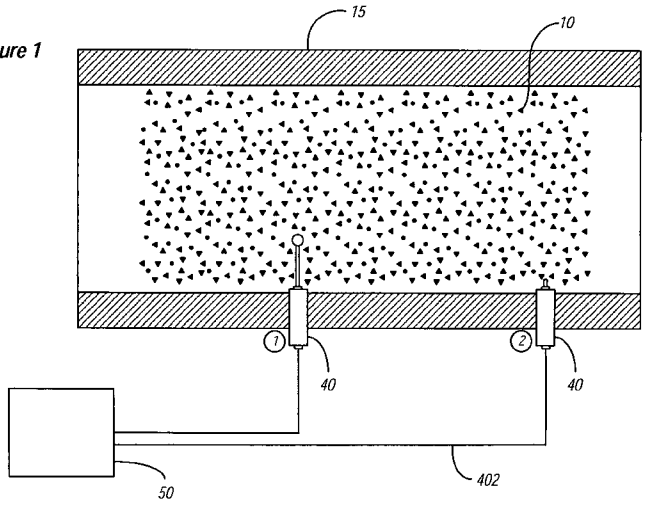
(54) **Title:** SYSTEMS AND METHODS FOR DETECTING LIQUID POOLING IN REACTOR SYSTEMS

Figure 1



(57) **Abstract:** Various methods and systems for detecting pooling of liquids in reactor systems are provided. In certain embodiments, the methods and systems include a polymerization reactor system such as a gas-phase reactor system.

WO 2009/096937 A1

SYSTEMS AND METHODS FOR DETECTING LIQUID POOLING IN REACTOR SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Serial No. 61/063,119, filed January 31, 2008, the disclosure of which is incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to detection of liquids, and more particularly, this invention relates to systems and methods for detecting liquid pooling in a reactor system.

BACKGROUND

[0003] In gas phase processes for the production of polyolefins such as polyethylene, one or more gaseous alkenes (*e.g.*, ethylene, propylene, hexene, octene, etc.), optionally, hydrogen, and other raw materials are converted to a polyolefin product. Generally, gas phase reactors typically include a fluidized bed reactor, a compressor, and a cooler. The reaction is maintained in a two-phase fluidized bed of granular polyethylene and gaseous reactants by the fluidizing gas which is passed through a distributor plate near the bottom of the reactor vessel. The reactor vessel is normally constructed of carbon steel and usually rated for operation at pressures up to about 50 bars (or about 3.1 MPa). A catalyst system is injected into the fluidized bed. Heat of reaction is transferred to the circulating gas stream. This gas stream is compressed and cooled in an external cycle line and then is reintroduced into the bottom of the reactor where it passes through a distributor plate. Make-up feedstreams and other components are added to maintain the desired reactant concentrations and production rates.

[0004] The polymerization reaction in fluidized bed reactors is an exothermic process, making it important in the overall process to remove the generated heat of reaction to keep the operating temperature of the reactor below crucial temperatures such as the resin and catalyst degradation temperatures as well as temperatures which cause polymers to agglomerate and plug the reactor.

Therefore, the amount of polymer that may be produced in a fluidized bed reactor of a given size in a specified time period is related to the amount of heat that can be withdrawn from the fluidized bed. Alternatively stated, the rate at which the heat of the polymerization reaction can be removed is an important capacity limitation of gas phase polymerization reactors.

[0005] Operating a gas phase polymerization reactor in a condensed mode where a cycle gas stream is cooled to a temperature below the dew point of the cycle gas stream to form a mixture comprising a liquid phase and a gas phase is a typical way to remove the heat of the polymerization reaction. This mixture comprising the liquid phase and the gas phase is cycled back to the reactor and injected into the fluidized bed.

[0006] In a process utilizing condensing mode operation, the gas-liquid ratio should be maintained at a level sufficiently high to keep the liquid phase entrained in the gas phase of the cycle stream fed to the reactor. However, an excessive amount of condensation can lead to liquid pooling in the bottom head of the reactor, the area below the distributor plate. Such liquid pooling is often a "cloud" or mist of minute liquid droplets suspended in the gas phase, and can reach thousands of pounds of suspended liquid. This liquid pooling can lead to fluidized bed instability problems. For example, a drop in the condensing agent concentration in the cycle gas results in reduced heat removal efficiency which may lead to temperatures exceeding the polymer melt point.

[0007] Furthermore, in a process utilizing condensed mode operation at high levels of condensation, undesirably high levels of liquid phase can exist in the lower sections of the fluidized bed. This can lead to liquid entrainment out of the reactor along with the product during a product discharge event. This liquid entrainment can reduce the fill efficiency of the product discharge system and increase the load on downstream vapor recovery systems. Additionally, if the condensed liquid is separated from the cycle gas and fed into the reactor through nozzles, the capacity of the liquid pump and liquid injection nozzle may become a limitation.

[0008] For example, during the summer months, the warmer ambient temperatures can adversely affect production rates by making it more difficult to cool the cycle stream to a temperature below the dew point of the cycle gas if an upper limit on the condensable component concentration is established. Additionally, increasing the concentration of the condensable component, *e.g.*, isopentane, can increase the molecular weight of the cycle gas, thus, increasing the energy consumption of the cycle gas compressor. Furthermore, high levels of isopentane may cause undue resin stickiness, increasing the probability of sheeting and chunking.

[0009] Therefore, there is a need in the polymer industry for alternative methods of operation to increase production rates from polymerization reactions other than by continuing to increase the amount of condensable component in the cycle gas.

SUMMARY

[0010] The present invention is broadly directed to various methods and systems for detecting liquid pooling in reactor systems, such as, for example, a polymerization reactor system. In certain embodiments, the methods and systems include a polymerization reactor system such as gas-phase reactor system. The invention is also broadly directed to various systems in which liquid pooling is detected.

[0011] In a class of embodiments, a method for detecting liquid pooling in a polymerization reactor system comprises contacting at least one electrical probe with a bulk material in a polymerization reactor system; monitoring the electrical probe; and determining the presence of a pool of liquid in the polymerization reactor system based on the monitoring.

[0012] In another class of embodiments, a method for detecting liquid pooling in a reactor vessel of a polymerization reactor system comprises contacting at least one electrical probe with a bulk material in a reactor vessel of a fluidized bed polymerization reactor system, the electrical probe being positioned between a cycle inlet and a distributor plate of the reactor vessel; monitoring the electrical

probe; and determining the presence of a pool of liquid in the reactor vessel of the polymerization reactor system based on the monitoring.

[0013] In yet another class of embodiments, a reactor system comprises at least one reactor vessel; and at least one electrical probe in contact with a bulk material inside the reactor system, wherein the electrical probe is monitored for determining presence of a pool of liquid inside the reactor system.

[0014] In an additional class of embodiments, a method for detecting condensate in a polymerization reactor system comprises contacting at least one electrical probe with a bulk material in a polymerization reactor system; monitoring the electrical probe; and determining the presence of a condensate in the polymerization reactor system based on the monitoring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Figure 1 is a schematic representation of the general methods, systems, and/or apparatuses of certain embodiments of the invention.

[0016] Figure 2 is a schematic representation of the general methods, systems, and/or apparatuses of certain embodiments of the invention illustrating implementation in a fluidized bed polymerization reactor.

[0017] Figure 3 is a schematic representation of an apparatus of an embodiment of the invention.

[0018] Figure 4 is a chart showing the effects of liquid pooling on an electrical probe reading, a current draw at the cycle gas compressor, and a condensing agent level.

[0019] Figure 5 is a chart showing a correlation of electrical probe readings during dry mode operation, a transition from dry mode operation to condensed mode operation, and during condensed mode operation.

DETAILED DESCRIPTION

[0020] Before the present compounds, components, compositions, devices, softwares, hardwares, equipments, configurations, schematics, systems, and/or

methods are disclosed and described, it is to be understood that unless otherwise indicated this invention is not limited to specific compounds, components, compositions, devices, softwares, hardwares, equipments, configurations, schematics, systems, methods, or the like, as such may vary, unless otherwise specified. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting.

[0021] It must also be noted that, as used in the specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless otherwise specified.

[0022] While the present invention is applicable to gas phase polyolefin production in a condensed or supercondensed mode (collectively referred to as a "condensed mode") wherein the cycle gas stream is cooled to a temperature below the dew point of the cycle gas stream to form a mixture comprising a liquid phase and a gas phase, and which may also contain a minor amount of carried over solid polymer particles, the broad concepts and teachings herein also have applicability to many types of processes, including but not limited to, gas phase, gas/solid phase, liquid/solid phase, gas/liquid phase, and gas/liquid/solid phase reactor systems including polymerization reactor systems; gas phase, gas/solid phase, liquid/solid phase, gas/liquid phase, and gas/liquid/solid phase mass transfer systems; gas phase, gas/solid phase, liquid/solid phase, gas/liquid phase, and gas/liquid/solid phase mixing systems; gas phase, gas/solid phase, liquid/solid phase, gas/liquid phase, and gas/liquid/solid phase heating or cooling systems; etc.

[0023] For ease of understanding of the reader, as well as to place the various embodiments of the invention in a context, much of the following description shall be presented in terms of a commercial, gas phase polyethylene reactor system. It should be kept in mind that this is done by way of non-limiting example only.

[0024] A general method of the invention can be described, for example, with reference to Figure 1, in which a bulk material 10 is bounded by a barrier 15 such as a vessel. Such bulk material can be gaseous, liquid and/or solid material. In a

reactor system, illustrative bulk materials may include one or more of reaction raw materials such as feedstocks, reaction products such as polymer particles, reaction adjuncts such as catalysts, reaction byproducts, condensing agents, *etc.*, and other materials. Thus, the bulk material may include substantially pure individual materials as well as combinations of materials, the material(s) being present in one or more phases. One or more electrical probes (designated generally collectively using the reference numeral "40," with multiple electrical probes designated more specifically in the various figures as electrical probes with circled numbers 1, 2, 3, *etc.* and in the associated text herein as 40-1, 40-2, *etc.*) are placed in contact with the bulk material. The response of the electrical probe 40 is monitored, *e.g.*, by processing unit 50, a person, etc., for determining presence of a pool of liquid in the polymerization reactor system based on the monitoring.

[0025] In a further generally preferred approach of the general method, with reference to Figure 2, an electrical probe 40 in contact with bulk material 10 in a fluidized bed polymerization reactor system 100 is monitored for purposes of determining the presence of a pool of liquid in the reactor vessel 110 of the polymerization reactor system 100 based on the monitoring. According to the general method, at least one electrical probe 40 is placed in contact with a bulk material 10 in a reactor vessel 110 of a fluidized bed polymerization reactor system 100, the electrical probe 40 being positioned between a cycle inlet 126 and a distributor plate 128 of the reactor vessel. The electrical probe is monitored. The monitoring may include measuring the voltage or amperage of the probe relative to a reference, *e.g.*, a local ground 152, the reactor vessel 110 or equipment structure, etc. Based on a monitored response of the electrical probe 40, the presence of a pool of liquid in the reactor vessel can be determined.

[0026] In a further generally preferred approach of the general method, with reference to Figure 2, an electrical probe 40 in contact with bulk material 10 in a fluidized bed polymerization reactor system 100 is monitored for purposes of detecting condensate in a polymerization reactor system 100 based on the monitoring. According to the general method, at least one electrical probe 40 is placed in contact with a bulk material 10 in a fluidized bed polymerization reactor

system 100. The electrical probe is monitored. The monitoring may include measuring the voltage or amperage of the probe relative to a reference, *e.g.*, a local ground 152, the reactor vessel 110 or equipment structure, etc. Based on a monitored response of the electrical probe 40, the presence of a condensate in the reactor system can be determined.

[0027] Further details of fluidized bed polymerization reactor systems and electrical probes including specific apparatus adapted for such monitoring are described below, and each of the below-described details are specifically considered combinable in various combination with these and other generally preferred approaches described herein.

[0028] The present invention also includes devices and systems effective for detecting a pool of liquid and/or the presence of condensate according to the aforementioned methods. In general, such devices are systems or apparatus that comprise one or more electrical probes and some mechanism for detecting a change in electrical characteristic of the electrical probe(s).

[0029] A preferred general system of the invention can comprise an electrical probe 40 adapted to interface a barrier 15 (*e.g.*, vessel or reactor 110). The interfaced electrical probe may comprise a sensing element, and may be in communication with at least one or both of a data retrieval circuit or a signal processing circuit of the processing unit 50 that measures an amperage of a current between the electrical probe and some reference, *e.g.,* ground 152, reactor vessel 110, etc., or equivalently, a voltage differential between the electrical probe and some reference, *e.g.*, ground 152, reactor vessel 110, etc. Figure 2 illustrates connections to both a ground 152 and a reactor vessel 110 via conductors 154, 156, respectively.

[0030] In another preferred general embodiment, with reference to Figure 2, a reactor system 100 includes a reactor vessel 110 (also referred to interchangeably herewith as a reaction vessel), and may include a cycle line 122. An electrical probe 40 is in contact with a bulk material inside the reactor system. The electrical probe is monitored for determining presence of a pool of liquid inside the reactor system.

[0031] In another preferred general embodiment, with reference to Figure 2, a fluidized bed polymerization reactor system 100 includes a reactor vessel 110 having a distributor plate 128. An electrical probe 40 is positioned above a hole in the distributor plate. The electrical probe is monitored for determining presence of a pool of liquid inside the reactor system.

MONITORING OF SINGLE- AND MULTI-PHASE SYSTEMS

[0032] In each of the aforementioned generally preferred approaches and/or embodiments, the electrical probe(s) can be employed for monitoring a variety of processes, including but not limited to, gas phase, gas/solid phase, liquid/solid phase, gas/liquid phase, and gas/liquid/solid phase reactor systems including polymerization reactor systems; gas phase, gas/solid phase, liquid/solid phase, gas/liquid phase, and gas/liquid/solid phase mass transfer systems; gas phase, gas/solid phase, liquid/solid phase, gas/liquid phase, and gas/liquid/solid phase mixing systems; gas phase, gas/solid phase, liquid/solid phase, gas/liquid phase, and gas/liquid/solid phase heating or cooling systems; etc.

FLUIDIZED BED SYSTEMS (INCLUDING FLUIDIZED BED POLYMERIZATION REACTOR SYSTEMS)

[0033] A fluidized bed can generally include a bed of particles in which the static friction between the particles is disrupted. In each of the aforementioned generally preferred approaches and/or embodiments, the fluidized bed system can be an open fluidized bed system or a closed fluidized bed system. An open fluidized bed system can comprise one or more fluids and one or more types of fluidized solid particles and having one or more fluidized bed surfaces that are exposed to an open uncontrolled atmosphere. For example, an open fluidized bed system can be an open container such as an open-top tank or an open well of a batch reactor or of a parallel batch reactor (*e.g.*, microtiter chamber). Alternatively, the fluidized bed system can be a closed fluidized bed system. A closed fluidized bed system can comprise one or more fluids and one or more types of fluidized particles that are generally bounded by a barrier so that the fluids and particles are constrained. For example, a closed fluidized bed system

may include a pipeline (*e.g.*, for particle transport); a recirculating fluidized bed system, such as the fluidized bed polymerization reactor system of Figure 2 (discussed above and below); any of which may be associated with various residential, commercial and/or industrial applications.

[0034] A closed fluidized bed system can be in fluid communication with an open fluidized bed system. The fluid communication between a closed fluidized bed system and an open fluidized bed system can be isolatable, for example, using one or more valves. Such isolation valves can be configured for unidirectional fluid flow, such as for example, a pressure relief valve or a check valve. In general, the fluidized bed system (whether open or closed) can be defined by manufactured (*e.g.*, man-made) boundaries comprising one or more barriers. The one or more barriers defining manufactured boundaries can generally be made from natural or non-natural materials. Also, in general, the fluidized bed system (whether open or closed) can be a flow system such as a continuous flow system or a semi-continuous flow (*e.g.*, intermittent-flow) system, a batch system, or a semi-batch system (sometimes also referred to as a semi-continuous system). In many instances, fluidized bed systems that are flow systems are closed fluidized bed systems.

[0035] The fluidized bed in preferred embodiments is generally formed by flow of a gaseous fluid in a direction opposite gravity. The frictional drag of the gas on the solid particles overcomes the force of gravity and suspends the particles in a fluidized state referred to as a fluidized bed. To maintain a viable fluidized bed, the superficial gas velocity through the bed must exceed the minimum flow required for fluidization. Increasing the flow of the fluidizing gas increases the amount of movement of the particles in the bed, and can result in a beneficial or detrimental tumultuous mixing of the particles. Decreasing the flow results in less drag on the particles, ultimately leading to collapse of the bed. Fluidized beds formed by gases flowing in directions other than vertically include particles flowing horizontally through a pipe, particles flowing downwardly *e.g.*, through a downcomer, *etc.*

[0036] Fluidized beds can also be formed by vibrating or otherwise agitating the particles. The vibration or agitation keeps the particles in a fluidized state.

FLUIDIZED BED POLYMERIZATION REACTOR SYSTEMS

[0037] In each of the aforementioned generally preferred approaches and/or embodiments, a fluidized bed system can include a fluidized bed polymerization reactor system. As briefly noted above, gas phase polymerization reactions may be carried out in fluidized bed polymerization reactors, and can also be formed in stirred or paddle-type reaction systems (*e.g.*, stirred bed systems) which include solids in a gaseous environment. While the following discussion will feature fluidized bed systems, where the present invention has been found to be preferred and especially advantageous, it is to be understood that the general concepts relating to the use of the electrical probes for liquid pooling detection, which are discussed relevant to the preferred fluidized bed systems, are also adaptable to the stirred or paddle-type reaction systems as well. The present invention is not limited to any specific type of gas phase reaction system.

[0038] In very general terms, a conventional fluidized bed polymerization process for producing resins and other types of polymers is conducted by passing a gaseous stream containing one or more monomers continuously through a fluidized bed reactor under reactive conditions and in the presence of catalyst at a velocity sufficient to maintain the bed of solid particles in a suspended condition. A continuous cycle is employed where the cycling gas stream, otherwise known as a cycle stream or fluidizing medium, is heated in the reactor by the heat of polymerization. The hot gaseous stream, also containing unreacted gaseous monomer, is continuously withdrawn from the reactor, compressed, cooled and recycled into the reactor. Product is withdrawn from the reactor and make-up monomer is added to the system, *e.g.*, into the cycle stream or reactor vessel, to replace the polymerized monomer. See for example U.S. Pat. Nos. 4,543,399, 4,588,790, 5,028,670, 5,317,036, 5,352,749, 5,405,922, 5,436,304, 5,453,471, 5,462,999, 5,616,661, 5,668,228, and 6,689,847. A basic, conventional fluidized bed system is illustrated in Figure 2. The reactor vessel 110 comprises a reaction zone 112 and a velocity reduction zone 114. While a reactor configuration

comprising a generally cylindrical region beneath an expanded section is shown in Figure 2, alternative configurations such as a reactor configuration comprising an entirely or partially tapered reactor may also be utilized. In such configurations, the fluidized bed can be located within a tapered reaction zone but below a region of greater cross-sectional area which serves as the velocity reduction zone of the more conventional reactor configuration shown in Figure 2.

[0039] In general, the height to diameter ratio of the reaction zone can vary in the range of about 2.7:1 to about 5:1. The range may vary to larger or smaller ratios and depends mainly upon the desired production capacity. The cross-sectional area of the velocity reduction zone 114 is typically within the range of from about 2.5 to about 2.9 multiplied by the cross-sectional area of the reaction zone 112.

[0040] The reaction zone 112 includes a bed of growing polymer particles, formed polymer particles and a minor amount of catalyst all fluidized by the continuous flow of polymerizable and modifying gaseous components, including inerts, in the form of make-up feed and cycle fluid through the reaction zone. To maintain a viable fluidized bed, the superficial gas velocity through the bed must exceed the minimum flow required for fluidization which is typically from about 0.2 to about 0.5 ft/sec. for polyolefins. Preferably, the superficial gas velocity is at least 0.2 ft/sec above the minimum flow for fluidization or from about 0.4 to about 0.7 ft/sec. Ordinarily, the superficial gas velocity will not exceed 5.0 ft/sec and is usually no more than about 2.5 ft/sec.

[0041] On start-up, the reactor is generally charged with a bed of particulate polymer particles before gas flow is initiated. Such particles help to prevent the formation of localized "hot spots" when catalyst feed is initiated. They may be the same as the polymer to be formed or different. When different, they are preferably withdrawn with the desired newly formed polymer particles as the first product. Eventually, a fluidized bed consisting of desired polymer particles supplants the start-up bed.

[0042] Fluidization is achieved by a high rate of fluid cycle to and through the bed, typically on the order of about 50 times the rate of feed or make-up fluid. This high rate of cycle provides the requisite superficial gas velocity necessary to

maintain the fluidized bed. The fluidized bed has the general appearance of dense mass of individually moving particles as created by the percolation of gas through the bed. The pressure drop through the bed is equal to or slightly greater than the weight of the bed divided by the cross-sectional area.

[0043] Referring again to Figure 2, make-up fluids can be fed at point 118 via cycle line 122. The composition of the cycle stream is typically measured by a gas analyzer 121 and the composition and amount of the make-up stream is then adjusted accordingly to maintain an essentially steady state composition within the reaction zone. The gas analyzer 121 can be positioned to receive gas from a point between the velocity reduction zone 114 and heat exchanger 124, preferably, between compressor 130 and heat exchanger 124.

[0044] To ensure complete fluidization, the cycle stream and, where desired, at least part of the make-up stream can be returned through cycle line 122 to the reactor, for example at inlet 126 below the bed. Preferably, there is a gas distributor plate 128 above the point of return to aid in fluidizing the bed uniformly and to support the solid particles prior to start-up or when the system is shut down. The stream passing upwardly through and out of the bed helps remove the heat of reaction generated by the exothermic polymerization reaction.

[0045] The portion of the gaseous stream flowing through the fluidized bed which did not react in the bed becomes the cycle stream which leaves the reaction zone 112 and passes into the velocity reduction zone 114 above the bed where a major portion of the entrained particles drop back onto the bed thereby reducing solid particle carryover.

[0046] The cycle stream is then compressed in compressor 130 and passed through heat exchanger 124 where the heat of reaction is removed from the cycle stream before it is returned to the bed. Note that the heat exchanger 124 can also be positioned before the compressor 130.

[0047] The cycle stream exiting the heat exchange zone is then returned to the reactor at its base and thence to the fluidized bed through gas distributor plate 128. A fluid flow deflector 132 is preferably installed at the inlet 126 to the reactor

vessel 110 to prevent contained polymer particles from settling out and agglomerating into a solid mass and to maintain entrained or to re-entrain any particles or liquid which may settle out or become disentrained.

[0048] In this embodiment, polymer product is discharged from line 144. Although not shown, it is desirable to separate any fluid from the product and to return the fluid to the reactor vessel 110.

[0049] In accordance with an embodiment of the present invention, the polymerization catalyst enters the reactor in solid or liquid form at a point 142 through line 148. If the catalyst requires the use of one or more co-catalysts, as is usually the case, the one or more cocatalysts may be introduced separately into the reaction zone where they will react with the catalyst to form the catalytically active reaction product. However the catalyst and cocatalyst(s) may be mixed prior to their introduction into the reaction zone.

[0050] The reactor system 100 shown in Figure 2 is particularly useful for forming polyolefins such as polyethylene, polypropylene, *etc.* Process conditions, raw materials, catalysts, etc. for forming various polyolefins and other reaction products are found in the documents referenced herein. Illustrative process conditions for polymerization reactions in general are listed below to provide general guidance.

[0051] The reaction vessel, for example, has an inner diameter of at least about 2 feet, and sometimes greater than about 20 feet.

[0052] The reactor pressure in a gas phase process may vary from about 100 psig (690 kPa) to about 600 psig (4138 kPa), preferably in the range of from about 200 psig (1379 kPa) to about 400 psig (2759 kPa), more preferably in the range of from about 250 psig (1724 kPa) to about 350 psig (2414 kPa).

[0053] The reactor temperature in a gas phase process may vary from about 30°C to about 120°C, preferably from about 60°C to about 115°C, more preferably in the range of from about 70°C to 110°C, and most preferably in the range of from about 70°C to about 95°C.

[0054] Other gas phase processes contemplated include series or multistage polymerization processes. Also gas phase processes contemplated by the invention include those described in U.S. Pat. Nos. 5,627,242, 5,665,818 and 5,677,375, and European publications EP-A-0 794 200, EP-B1-0 649 992, EP-A-0 802 202, and EP-B-634 421.

[0055] In any of the embodiments described herein, the polymerization reaction system may be operated in a condensed mode, as described below.

[0056] In an embodiment, the reactor utilized in the present invention is capable of producing greater than 500 lbs of polymer per hour (227 Kg/hr) to about 300,000 lbs/hr (136,050 Kg/hr) or higher of polymer, preferably greater than 1000 lbs/hr (455 Kg/hr), more preferably greater than 10,000 lbs/hr (4540 Kg/hr), even more preferably greater than 25,000 lbs/hr (11,300 Kg/hr), still more preferably greater than 35,000 lbs/hr (15,900 Kg/hr), still even more preferably greater than 50,000 lbs/hr (22,700 Kg/hr) and most preferably greater than 65,000 lbs/hr (29,000 Kg/hr) to greater than 100,000 lbs/hr (45,500 Kg/hr).

CONDENSED MODE

[0057] In any of the embodiments described herein, the polymerization reaction system may be operated in a condensed or supercondensed mode (collectively "condensed mode"), where an inert condensable fluid is introduced to the process to increase the cooling capacity of the reactor system. These inert condensable fluids are typically referred to as (induced) condensing agents or ICA's. One particularly preferred condensing agent is isopentane, though others can be used. For further details of a condensed mode processes *see* U.S. Patent Nos. 5,342,749 and 5,436,304 and U.S. Patent Appl. Pub No. 2005/0267268 A1.

[0058] By causing condensation of the condensing agent, more heat can be removed from the reaction system, thereby greatly increasing the polymer production rate.

[0059] In one approach, the cycle gas stream is cooled to a temperature below the dew point of the cycle gas stream to form a mixture comprising a liquid phase and a gas phase, and which may also contain a minor amount of carried over solids

such as polymer particles, catalyst, etc. In an embodiment, operation in condensation mode is carried out according to the method and apparatus in the U.S. Pat. No. 4,588,790, entitled "Method for Fluidized Bed Polymerization," filed on May 18, 1986. Embodiments of the present disclosure may also follow the practices found in other prior patents disclosing condensing mode polymerization operations such as in U.S. Pat. Nos. 4,543,399, 5,436,304, 5,462,999, 6,391,985, 5,352,749, 5,405,922, 6,455,644, and European Patent no. 0,803,519 A1.

[0060] In one approach, an about constant condensate content in the cycle line may be maintained at less than or equal to about 20 weight percent and may be controlled by adjusting the condensing agent concentration in the polymerization reactor. Generally, using isopentane as an example of a condensing agent, increasing the isopentane increases the amount of condensation for a constant temperature and pressure. Typically the isopentane concentration is established such that the cycle gas outlet temperature is reasonable, *i.e.*, operation is not constrained by the cooling water temperature fed to the heat exchanger. Examples of using isopentane as a non-polymerizing material added to the cycle gas stream can also be found in U.S. Pat. Nos. 4,588,790, 5,436,304, 5,462,999, 6,391,985, 5,352,749, and 5,405,922. Isopentane may commonly be used because its molecular weight is high enough to condense but is low enough that it can be removed from the polymer in subsequent downstream processing, *e.g.*, degassing.

[0061] In an embodiment, the gas analyzer is used to control the amounts of monomer and comonomers, as well as an amount of a condensing agent to maintain an about constant condensate content in the cycle line. However, as mentioned above, the amount of condensing agent detected in the reactor system may be affected by pooling of the condensing agent in the reactor system. Therefore, particularly preferred embodiments provide coordination between the liquid pooling detection described herein and the amount of condensing agent added to the reactor system.

OTHER TYPES OF SYSTEMS

[0062] Slower moving masses of particles, while considered "fluidized" for purposes of the present description, are also referred to in the art as "moving beds." Moving beds include particles in such things as mass flow bins, downcomers, *etc.* where solids are slowly moving through a vessel.

[0063] Stirred bed system, while considered "fluidized" for purposes of the invention, include beds stirred or otherwise agitated by a member such as a paddle or plunger rotating or moving through the bed (*e.g.*, stirred bed reactor, blender, *etc.*). Other types of stirred bed systems can be formed by a rotating drum (*e.g.*, with or without internal baffles to enhance mixing), a vessel moving in a see-saw manner, agitation including ultrasonic vibrations applied to the particles or their container, *etc.*

FLUIDS

[0064] In general, for example, electrical probes can be used in connection with liquids and/or gasses having a wide range of fluid properties, such as a wide range of viscosities, densities and/or dielectric constants (each such property being considered independently or collectively as to two or more thereof). For example, liquid fluids can generally have viscosities ranging from about 0.1 cP to about 100,000 cP, and/or can have densities ranging from about 0.0005 g/cc^3 to about 20 g/ cc^3 and/or can have a dielectric constant ranging from about 1 to about 100. In many embodiments of the invention, the bulk material is a gaseous fluid. Gaseous fluids can, for example, generally have viscosities ranging from about 0.001 to about 0.1 cP, and/or can have densities ranging from about 0.0005 to about 0.1 g/cc^3 and/or can have a dielectric constant ranging from about 1 to about 1.1.

[0065] The bulk material can include relatively pure gaseous elements (*e.g.*, gaseous N_2, gaseous O_2) and a relatively pure liquid. Other components can include other liquids and mixtures, solid, or gaseous compounds (*e.g.*, liquid or solid catalyst, gaseous monomer, air). The various systems of the inventions can also include single-phase or multi-phase mixtures of gases, solids and/or liquids,

including for example: two-phase mixtures of solids and gases (*e.g.*, fluidized bed systems), mixtures of gasses with a single type of particle, mixtures of gasses with different types of particles (*e.g.*, polymer and catalyst particles); and/or three-phase mixtures of gasses, liquids and solids (*e.g.*, fluidized bed with liquid catalyst being added). Particular examples of preferred fluids are described herein, including in discussion below regarding preferred applications of the methods and devices of the invention.

[0066] The liquids sought to be detected by the present invention include any type of liquid capable of being detected by the general methods presented herein in any of the various types of systems described herein.

OPERATING CONDITIONS

[0067] The operating conditions of the reactor and other systems are not narrowly critical to the invention. While general operating conditions have been provided above for fluidized bed polymerization reactor systems, fluidized and nonfluidized bed systems can, in addition to those listed above, have widely varying process conditions, such as temperature, pressure, fluid flowrate, *etc.*

ELECTRICAL PROBES

[0068] In general, as noted above, the particular electrical probe of the methods and systems and apparatus of the present invention is not limited. Generally, the electrical probes useful in connection with this invention are adapted to be in contact with a bulk material. By monitoring the electrical probe, the presence of liquid pooling in the bulk material can be detected. By "monitoring" what is meant is to generate data associated with an electrical response of the electrical probe. The data association with the electrical response in this context means data (typically obtained or collected as a data stream over some time period such as a sensing period), including both raw data (directly sensed data, *e.g.*, level of current or voltage) or processed data, can be directly informative of or related to (*e.g.*, through correlation and/or calibration) an absolute value of a property and/or a relative value of a property (*e.g.*, a change in a property value over time), and can be used to determine the presence of liquid pooling. In many applications, the

raw data can be associated with a property of interest using one or more correlations and/or using one or more calibrations. Typically such correlations and/or calibrations can be effected electronically using signal processing circuitry, either with user interaction or without user interaction (*e.g.*, automatically).

[0069] Particular electrical probes can be selected based on a needed or desired property (or properties) of interest, and on required specifications as to sensitivity, universality, fluid-compatibility, system-compatibility, as well as on business considerations such as availability, expense, *etc.* In one approach, an electrical capacitance probe is used. Such a probe may also be usable to determine a level of static electricity of solids in the bulk material.

[0070] The electrical probe can include, for example, an electrically conductive member or surface designed to contact a bulk material. Various types of electrical probes can be employed, including for example the electrical probes shown in Figure 3.

[0071] In one approach, with reference to Figures 1 and 3, an electrical probe 40 includes an electrically conductive member 18 coupled to but preferably insulated from the barrier 15. With reference to Figure 3, the electrical probe in one preferred embodiment includes an electrically conductive rod 18 coupled to a support plate, *e.g.*, by welding. The support plate may be electrically isolated from an electrically conductive barrier 15, in this case the reactor vessel 110, by an insulator 404. The electrical lead 402 is connected to the processing unit 50.

[0072] In a further approach, with reference to Figures 1 and 3, the electrical probe 40 may include a rod with an electrically conductive member, disc or ball on the end of the rod.

[0073] In one approach, no external electrical signal is applied to the electrical probe. Accordingly, the voltage level or current is generated by contact between the electrical probe and the bulk material.

[0074] Some or all of the electrical probes in the various embodiments may be coupled to a ground, which may or may not be at some potential. Switches, resistors, and other components may be present between the electrical probes and ground. The ground may be a true ground, or may be biased to some potential. In other approaches, the ground may be the barrier 15 itself, such as the reactor vessel of a polymerization reactor system. In one approach, the amperage of the current passing from the electrical probe and ground can be monitored for indication of presence of liquid pooling. In another approach, the voltage differential between the electrical probe and ground can be monitored for indication of presence of liquid pooling. In other embodiments, some or all of the electrical probes are isolated from a ground.

[0075] While the electrical probe 40 is described above and below in terms of being coupled to an external processing unit 50, the circuitry may also be implemented with the electrical probe in a single standalone unit. As one preferred example, the electrical probe 40 may comprise an electrical probe, a signal processing circuit (*e.g.,* comprising amplifier circuitry), and/or a data retrieval circuit (*e.g.* comprising data memory circuitry, perhaps adapted for recording raw data received from the electrical probe).

PROBE POSITIONING

[0076] The electrical probes 40 can be placed in many different positions along or in the system containing the bulk material.

[0077] In certain embodiments, it is advantageous to locate an electrical probe for liquid pooling detection at particular points inside the process. In this way, it is possible to identify and troubleshoot liquid pooling which occur inside the process. In the fluidized bed polymerization reactor system 100 of Figure 2, for example, most pooling of the condensing agent is between the distributor plate 128 and cycle inlet 126 at the bottom of the reactor vessel 110. An electrical probe 40 located near the inlet 126 is in direct contact with the flowing stream between the cycle injection point and the fluidized bed. At this location the probe

is in continuous contact with both the reactor "cycle gas" as well as the fresh feed entering the cycle line at point 118.

[0078] In the fluidized bed polymerization reactor system 100 of Figure 2, for example, some electrical probes, *e.g.,* 40-1, 40-2, 40-3 have sensing surfaces positioned in the reactor vessel 110. Note that while three electrical probes 40-1, 40-2, 40-3 are shown, typically only one or two electrical probes will be used in a particular implementation.

[0079] Electrical probe 40-1 is mounted to the fluid flow deflector 132 above the cycle inlet 126, as shown in Figure 2 and also shown in Figure 3. The electrical probe is in direct contact with the cycle gases and liquids rising through the cycle inlet 126.

[0080] With continued reference to Figure 2, electrical probes 40-1 is mounted to the fluid flow deflector 132 and is electrically insulated from the fluid flow deflector 132, as also shown in Figure 3. This electrical probe is located at the inlet of the reactor vessel 110 and is in direct contact with the flowing hydrocarbon and condensate stream as it enters the expansion zone just below the distributor plate. In a preferred embodiment, the electrical probe extends several inches into the flowing stream. The electrical probe shown in Figures 2 and 3 may also function as a static probe. The electrically conductive rod serves as an electrode. Entrained solid and liquid particles in the cycle flow impact the electrode and transfer electrical charge. The rate of charge flow can be measured as a current signal or equivalently a voltage differential by the processing unit 50.

[0081] Electrical probe 40-2 is another type of electrical probe that is mounted to the fluid flow deflector 132 above the cycle inlet 126, as shown in Figure 2. The electrical probe is in direct contact with the cycle gases and liquids rising through the cycle inlet 126 and is electrically insulated from the fluid flow deflector 132.

[0082] Electrical probes 40-3 is a ported sensor that passes through the reactor vessel 110 such that the sensing surface of each electrical probe 40 is exposed to the fluidized particles in the reaction zone 112.

[0083] In one approach, the electrical probe is located between the distributor plate and the cycle inlet is at a distance from the distributor plate that is between about one quarter and about three quarters of a distance between the cycle inlet and the distributor plate of the reactor vessel, more preferably at a distance from the distributor plate that is between about three eights and about five eights of a distance between the cycle inlet and the distributor plate of the reactor vessel. The electrical probe is also preferably positioned towards the center axis of the reactor vessel, though could also be located towards the sides of the reactor vessel. In one particularly preferred approach, an electrical probe is located about half way between the cycle inlet and the distributor plate, and about on a vertical axis of the reactor vessel.

[0084] In another approach, the electrical probe is positioned at a distance from the distributor plate that is between about 50% and about 99% of a distance between the cycle inlet and the distributor plate of the reactor vessel. For example, the electrical probe may be positioned at a distance from the distributor plate that is between about 50% and about 75%, about 75% to about 99%, about 90% to about 99%, etc. of a distance between the cycle inlet and the distributor plate of the reactor vessel

[0085] The electrical probe may also function as a static probe, as described in U.S. Patent No. 6,831,140 to Muhle *et al.* Accordingly, the electrical probe in one embodiment of the present invention is capable of performing the dual roles of liquid pooling detection and static level measurement. Such dual-mode monitoring would typically be performed when operating in an enhanced dry mode, as most solids in the cycle line become entrained in the liquid condensate in condensed mode. For example, monitoring of static changes in a fluidized bed gas phase reaction is a useful method for detecting changes in the reactor which indicate the onset of discontinuities such as sheeting. The sooner these changes can be detected, the sooner corrective action can be taken, thereby reducing the chances of a discontinuity in the reactor. Thus, such an embodiment allows detection of changes in the static charges in the reactor early on. This early detection allows for better control of the reactor.

[0086] Electrical probes 40-2 and 40-3 may take the form of any of the electrical probes described above and below, and may be used to detect liquid pooling and/or static levels.

[0087] In various embodiments, an electrical probe of the present invention located at one position may be used in combination with at least one other electrical probe to provide, for example, a comparative measure of liquid pooling and/or location. More particularly, the extent of signal change of each probe is measured. Calculating the difference in the net signal change for each probe is then used to determine the difference between two probes. This in turn provides a net measure of the liquid pool size and/or location at various locations in the system. For example, referring to Figure 2, the current of electrical probe 40-1 can be compared to the current of electrical probe 40-3. If pooling is detected at electrical probe 40-3, but not at electrical probe 40-1, it is likely that the pool is small, and remedial action can be taken. If, on the contrary, pooling is detected at both electrical probes 40-1 and 40-3, then it is likely that a large pool has formed and remedial action should be taken immediately to diminish and/or eliminate the pool of the liquid. Such remedial action may include reducing or stopping a feed rate of the liquid, altering a flow rate of the cycle influent in order to change the hydrodynamics of the fluids below the distributor plate, etc.

PROCESSING UNIT

[0088] With reference to Figures 1, 2 and 3, the processing unit 50 is coupled to the leads 402 from the electrical probes 40. The processing unit 50 may be a simple monitoring device. Illustrative processing units 50 include an electrometer or low current meter (picoammeter), a digital volt meter, an ohmmeter, an oscilloscope, or the like. More complex processing units are also contemplated, such as computerized systems. The processing unit may be coupled to other system components 160 such as process controllers.

[0089] In preferred embodiments, one or more circuit modules of the signal processing circuit and/or the data retrieval circuit can be implemented and realized as an application specific integrated circuit (ASIC). Portions of the processing

can also be performed in software in conjunction with appropriate circuitry and/or a host computing system.

[0090] As mentioned above, while the electrical probe 40 is described above and below in terms of being coupled to an external processing unit 50, the circuitry may also be implemented with the electrical probe in a single standalone unit. As an example, the electrical probe 40 may comprise an electrical probe, a signal processing circuit (*e.g.,* comprising amplifier circuitry), and/or a data retrieval circuit (*e.g.,* comprising data memory circuitry, perhaps adapted for recording raw data received from the electrical probe).

[0091] In one approach, during steady-state operations, the processing unit measures about a constant current between a ground and the electrical probe. Formation of a liquid pool is detected as a change in the amperage.

[0092] In another approach, during steady-state operations, the processing unit measures about a constant voltage differential between a ground and the electrical probe. A pool of liquid is detected as a change in the voltage differential.

BARRIER INTERFACE

[0093] As described above in connection with the methods, systems, and apparatus (*e.g.,* in connection with Figures 1, 2 and 3), a ported electrical probe or ported electrical probe subassembly can be interfaced with the fluidized or nonfluidized system across a barrier 15 that defines at least a portion of the fluidized or nonfluidized system. Preferably, the ported electrical probe, the electrical probe or electrical probe subassembly is interfaced across the barrier without substantially compromising the integrity of the barrier.

[0094] With reference to Figure 3 in some embodiments, the electrical probe 40 is connected to an electrical lead 402 which is routed to a reactor vessel exit point which is designed to insulate the electrical lead from the reactor body. For example, the electrical lead may be from the high pressure reactor environment through a mechanical seal 408 which is or includes an insulator. In some embodiments, a pressure sealing gland, such as those commercially available from

Conax Buffalo Technologies, Buffalo, NY, may be used as the insulator/seal 408 at the exit point.

[0095] The electrical lead 402 may be housed in an insulative covering. With reference to Figure 3, in embodiments where the electrical lead is positioned inside the barrier 15, a protective covering may be provided. The protective covering may replace or supplement an insulative covering (if any). An illustrative electrical lead includes a mineral insulation cable.

GENERAL MONITORING APPLICATIONS

[0096] The methods and systems and apparatus of the invention can be used to detect pooling of a liquid in various systems. The invention can be advantageously used, for example, to detect liquid pooling in bulk materials. The invention in some embodiments can also advantageously be used to characterize a level of static charge in a system.

[0097] As described above in connection with the generally preferred approaches, systems, and apparatuses (*e.g.*, in connection with Figures 1, 2 and 3), the electrical probe is interfaced with one or more bulk materials. The electrical probe is operational for detecting liquid pooling in the bulk material. The liquid pooling detection can be performed in real time, in near real time, or in time-delayed modes of operation.

MONITORING OF SYSTEMS

Liquid Pool Detection

[0098] In the methods and systems and apparatuses of the invention, the particular liquid being detected is not narrowly critical. In general, the liquid of interest will depend on the composition of the bulk material and the significance of the monitoring with respect to a system in a particular commercial application. The monitoring for a particular system may also depend to some extent on the location of the electrical probe.

[0099] In any of the approaches described herein (above and below), the response of the electrical probe may be caused by the contact of the bulk material against

the electrical probe alone (passive mode), or by a combination of the contact of the bulk material and an external stimulus (active mode). Further, where multiple electrical probes are present at different positions along the barrier, the electrical probe responses may be used to determine relative measurements. For example, the responses of electrical probes 40-1 and 40-3 of Figure 2 can indicate a relative size of a liquid pool at the bottom of the reaction zone without the need to quantify the data.

[00100] In a passive mode, no external electrical signal is applied to the electrical probe. The electrical probe becomes charged by contact with the bulk material thereagainst. For example, the electrical probes 40 in Figure 2 become charged primarily by contacting entrained solids and liquids in the cycle gas. In one approach, during steady-state operations, a current or voltage will be generated between the electrical probe and ground at a relatively constant level. Formation of a liquid pool causes the current or voltage to change. This change in current or voltage reflects presence, absence, or a change in the level of liquid pooling.

[00101] In an active mode, an external electrical signal is applied to the electrical probe. In one approach, during steady-state operations, a current or voltage is present at the electrical probe at a relatively constant level. Introduction, removal, or change in a liquid pool from the bulk material causes the current or voltage level to change. This change in current or voltage reflects presence, absence, or a change in the level of liquid pooling.

[00102] Other changes in reactor conditions that occur concurrently with formation of a liquid pool may be used to verify or supplement any detection of liquid pool formation. For example, relatively small changes in the current draw by the cycle gas compressor (compressor amps) and condensing agent level (*e.g.* isopentane concentration) may also indicate pooling in the reactor bottom bell. For example, as shown in Figure 4, discussed below, the compressor amperage draw dropped concurrently with the change in electrical probe reading. Also, the concentration of isopentane detected by the gas analyzer also dropped concurrently with the change in electrical probe reading. Accordingly, one approach may require that at least two conditions are met before indicating formation of a pool.

[00103] The electrical probe may also be used to detect disappearance of the liquid pool as well.

DETECTION OF CONDENSATE, INCLUDING DETECTION OF TRANSITION BETWEEN DRY MODE OPERATION AND CONDENSED MODE OPERATION

[00104] In a similar manner to detecting pooling of a liquid, condensate may be detected by certain embodiments. Such embodiments are particularly useful for detecting formation of condensate when operating in dry mode. When operating in dry mode, crossing in and out of condensed mode may result in detrimental effects such as fouling of the distributor plate, etc. Further, it is generally difficult to calculate an extent of the condensation, absent highly advanced thermodynamics computational programming in the control systems and rapid, accurate analyzer data for all components in the stream.

[00105] As shown in Figure 5, the electrical probe signal responds to the presence of condensate.

[00106] Likewise, as apparent from the example of Figure 5, by monitoring the electrical probe, the transition from dry mode operation to condensed mode operation is readily observable. This is useful particularly at reactor system startup to identify an approximate time that condensed mode operation has begun. Further, the transition from condensed mode to dry mode can be similarly observed.

[00107] Also, as shown, the electrical probe response is loosely proportional to the percentage of the bulk material that has condensed. Thus, the response can be used to avoid recurring transitions between dry and condensed mode.

[00108] In general, the various systems, methods, and operating parameters for detecting pooling of liquid, as disclosed herein, may be used with little or no modification for detecting condensate and/or for detecting the transition between dry mode operation and condensed mode operation.

Remedial Actions

[00109] When liquid pooling and/or presence of condensate is detected, remedial action may be taken. In one approach, such remedial action may include reducing or stopping a feed rate of the liquid suspected of pooling. For example, when running in a condensed mode of operation in a fluidized bed polymerization reaction, a pool detected below the distributor plate is likely of the condensing agent. Accordingly, the feed rate of the condensing agent can be reduced or stopped until concentration of the condensing agent is reduced and the pool is satisfactorily diminished.

[00110] In another approach, the remedial action includes altering a flow rate of the cycle gas in order to change the hydrodynamics of the fluids below the distributor plate. Such a change should be performed slowly so as to avoid introduction of too much liquid and/or the entire pool into the reaction zone.

[00111] In yet another approach, the remedial action includes altering the composition below the distributor plate by varying the flow rate, temperature or pressure of the system. This will vary the size and incipient formation of the pool and/or formation of condensate.

EXAMPLES

[00112] It is to be understood that while the invention has been described in conjunction with the specific embodiments thereof, the foregoing description is intended to illustrate and not limit the scope of the invention. Other aspects, advantages and modifications will be apparent to those skilled in the art to which the invention pertains.

[00113] Therefore, the following examples are put forth so as to provide those skilled in the art with a complete disclosure and description of how to make and use the compounds of the invention, and are not intended to limit the scope of that which the inventors regard as their invention.

[00114] In each of the following examples, electrical probe measurements were made in an operable polyethylene fluidized bed reactor system similar to that shown in Figure 2. One electrical probe was positioned above the inlet of the

reactor vessel in direct contact with the flowing recycle stream as it enters the expansion zone just below the distributor plate. It was mounted on the annular disk shown in Figure 3. The probe extended about three inches into the flowing stream and was insulated from its mounting bracket. The electrical probe was connected to an electrical lead which was routed to a reactor exit point which was designed to insulate the electrical lead from the steel reactor body. The electrical probe was operated in passive mode.

[00115] With reference to Figure 4 during routine operations, the electrical probe provided a direct indication of initiation of condensed mode operation as shown in the attached plot at approximately 14:00 hr on Day 2. Subsequent to the detection of condensed operation, the probe detected the presence of a liquid pool forming in the bottom bell of the reactor vessel that occurred five times during the run period shown on the plot at about 12:30 on Day 3, 17:30 on Day 3, 03:00 on Day 4, 16:40 on Day 4 and 20:30 on Day 4. The presence of a liquid pool forming in the bottom bell of the reactor vessel was detected as a sharp drop in the static level detected from the electrical probe.

[00116] 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, as along as such steps, elements, or materials, do not affect the basic and novel characteristics of the invention, additionally, they do not exclude impurities and variances normally associated with the elements and materials used.

[00117] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, within a range includes every point or individual value between its end points even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper

limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[00118] All priority documents are herein fully incorporated by reference for all jurisdictions in which such incorporation is permitted and to the extent such disclosure is consistent with the description of the present invention. Further, 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 disclosure is consistent with the description of the present invention.

[00119] While the invention has been 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 invention as disclosed herein.

CLAIMS

What is claimed is:

1. A method for detecting liquid pooling in a polymerization reactor system comprising:

contacting at least one electrical probe with a bulk material in a polymerization reactor system;

monitoring the electrical probe; and

determining the presence of a pool of liquid in the polymerization reactor system based on the monitoring.

2. The method as recited in claim 1, wherein the electrical probe is an electrical capacitance probe.

3. The method as recited in any one of the preceding claims, wherein the electrical probe is also useable for determining a level of static electricity of solids in the bulk material.

4. The method as recited in any one of the preceding claims, wherein the liquid in the pool is primarily a condensing agent.

5. The method as recited in any one of the preceding claims, wherein the bulk material includes liquid, gaseous and solid phase materials.

6. The method as recited in any one of the preceding claims, wherein the electrical probe is positioned between a cycle inlet and a distributor plate of a reactor vessel of the polymerization reactor system.

7. The method as recited in claim 6, wherein the electrical probe is positioned at a distance from the distributor plate that is between about one quarter

and about three quarters of a distance between the cycle inlet and the distributor plate of the reactor vessel.

8. The method as recited in claim 7, wherein the electrical probe is positioned at a distance from the distributor plate that is between about three eights and about five eights of a distance between the cycle inlet and the distributor plate of the reactor vessel.

9. The method as recited in claim 6, wherein the electrical probe is positioned at a distance from the distributor plate that is between about 50% and about 99% of a distance between the cycle inlet and the distributor plate of the reactor vessel.

10. The method as recited in any one of the preceding claims, wherein the polymerization reactor system is operating in a condensed mode.

11. The method as recited in any one of the preceding claims, wherein the polymerization reactor system is operating in a supercondensed mode.

12. The method as recited in any one of the preceding claims, wherein monitoring the electrical probe includes monitoring a voltage differential or current flow between the electrical probe and a ground.

13. The method as recited in claim 12, wherein no external electrical signal is applied to the electrical probe, the voltage or current flow being generated by the electrical probe contacting the bulk material.

14. The method as recited in claim 12, wherein the ground is a reactor vessel of the polymerization reactor system.

15. The method as recited in any one of the preceding claims, further comprising detecting at least one other condition in the polymerization

reactor system, wherein the determining the presence of a pool of liquid in the polymerization reactor system is based on the monitoring and the at least one other condition.

16. The method as recited in any one of the preceding claims, further comprising taking a remedial action for diminishing the pool of the liquid.

17. A method for detecting liquid pooling in a reactor vessel of a polymerization reactor system comprising:

contacting at least one electrical probe with a bulk material in a reactor vessel of a fluidized bed polymerization reactor system, the electrical probe being positioned between a cycle inlet and a distributor plate of the reactor vessel;

monitoring the electrical probe; and

determining the presence of a pool of liquid in the reactor vessel of the polymerization reactor system based on the monitoring.

18. The method as recited in claim 17, wherein the electrical probe is an electrical capacitance probe.

19. The method as recited in any one of claims 17-18, wherein the electrical probe is also useable for determining a level of static electricity of solids in the bulk material.

20. The method as recited in any one of claims 17-19, wherein the liquid in the pool is primarily a condensing agent.

21. The method as recited in any one of claims 17-20, wherein the bulk material includes liquid, gaseous and solid phase materials.

22. The method as recited in any one of claims 17-21, wherein the electrical probe is positioned at a distance from the distributor plate that is between about one quarter and about three quarters of a distance between the cycle inlet and the distributor plate of the reactor vessel.

23. The method as recited in any one of claims 17-21, wherein the electrical probe is positioned at a distance from the distributor plate that is between about three eights and about five eights of a distance between the cycle inlet and the distributor plate of the reactor vessel.

24. The method as recited in any one of claims 17-21, wherein the electrical probe is positioned at a distance from the distributor plate that is between about 50% and about 99% of a distance between the cycle inlet and the distributor plate of the reactor vessel.

25. The method as recited in any one of claims 17-24, wherein the polymerization reactor system is operating in a condensed mode.

26. The method as recited in any one of claims 17-25, wherein the polymerization reactor system is operating in a supercondensed mode.

27. The method as recited in any one of claims 17-26, wherein monitoring the electrical probe includes monitoring a voltage differential or current flow between the electrical probe and a ground.

28. The method as recited in claim 27, wherein no external electrical signal is applied to the electrical probe, the voltage or current flow being generated by the electrical probe contacting the bulk material.

29. The method as recited in claim 27, wherein the ground is a reactor vessel of the polymerization reactor system.

30. The method as recited in any one of claims 17-29, further comprising detecting at least one other condition in the polymerization reactor system, wherein the determining the presence of a pool of liquid in the polymerization reactor system is based on the monitoring and the at least one other condition.

31. The method as recited in any one of claims 17-30, further comprising taking a remedial action for diminishing the pool of the liquid.

32. A reactor system comprising:
at least one reactor vessel; and
at least one electrical probe in contact with a bulk material inside the reactor system;
wherein the electrical probe is monitored for determining presence of a pool of liquid inside the reactor system.

33. The reactor system as recited in claim 32, wherein the reactor system is a gas-phase polymerization reactor system.

34. The reactor system as recited in any one of claims 32-33, wherein the reactor system is a operating in a condensed mode.

35. The reactor system as recited in any one of claims 32-33, wherein the reactor system is a operating in a supercondensed mode.

36. The reactor system as recited in any one of claims 32-35, wherein the electrical probe is also useable for determining a level of static electricity of solids in the bulk material.

37. The reactor system as recited in any one of claims 32-36, wherein the electrical probe is positioned in the reactor vessel of the reactor system.

38. The reactor system as recited in any one of claims 32-37, further comprising a distributor plate in the reactor vessel, wherein the electrical probe is positioned between the distributor plate of the reactor vessel and a cycle inlet to the reactor vessel.

39. The reactor system as recited in any one of claims 32-38, wherein the liquid in the pool is primarily a condensing agent.

40. The reactor system as recited in any one of claims 32-39, wherein the bulk material includes liquid, gaseous and solid phase materials.

41. The reactor system as recited in any one of claims 32-40, wherein the electrical probe is positioned between a cycle inlet and a distributor plate of a reactor vessel of the polymerization reactor system.

42. The reactor system as recited in claim 41, wherein the electrical probe is positioned at a distance from the distributor plate that is between about one quarter and about three quarters of a distance between the cycle inlet and the distributor plate of the reactor vessel.

43. The reactor system as recited in claim 42, wherein the electrical probe is positioned at a distance from the distributor plate that is between about three eights and about five eights of a distance between the cycle inlet and the distributor plate of the reactor vessel.

44. The reactor system as recited in claim 41, wherein the electrical probe is positioned at a distance from the distributor plate that is between about 50% and about 99% of a distance between the cycle inlet and the distributor plate of the reactor vessel.

45. The reactor system as recited in any one of claims 32-44, wherein monitoring the electrical probe includes monitoring a voltage or current flow between the electrical probe and a ground.

46. The reactor system as recited in claim 45, wherein no external electrical signal is applied to the electrical probe, the voltage or current flow being generated by the electrical probe contacting the bulk material.

47. The reactor system as recited in claim 45, wherein the ground is a reactor vessel of the polymerization reactor system.

48. The reactor system as recited in any one of claims 32-47, wherein monitoring the electrical probe includes monitoring a voltage differential between the electrical probe and a ground.

49. A method for detecting condensate in a polymerization reactor system comprising:

contacting at least one electrical probe with a bulk material in a polymerization reactor system;

monitoring the electrical probe; and

determining the presence of a condensate in the polymerization reactor system based on the monitoring.

50. The method as recited in claim 49, wherein the electrical probe is an electrical capacitance probe.

51. The method as recited in any one of claims 49-50, wherein the electrical probe is also useable for determining a level of static electricity of solids in the bulk material.

52. The method as recited in any one of claims 49-51, wherein the bulk material includes liquid, gaseous and solid phase materials.

53. The method as recited in any one of claims 49-52, wherein the electrical probe is positioned between a cycle inlet and a distributor plate of a reactor vessel of the polymerization reactor system.

54. The method as recited in claim 53, wherein the electrical probe is positioned at a distance from the distributor plate that is between about one quarter and about three quarters of a distance between the cycle inlet and the distributor plate of the reactor vessel.

55. The method as recited in claim 54, wherein the electrical probe is positioned at a distance from the distributor plate that is between about three eights and about five eights of a distance between the cycle inlet and the distributor plate of the reactor vessel.

56. The method as recited in claim 53, wherein the electrical probe is positioned at a distance from the distributor plate that is between about 50% and about 99% of a distance between the cycle inlet and the distributor plate of the reactor vessel.

57. The method as recited in any one of claims 49-56, wherein the polymerization reactor system is operating primarily in a dry mode.

58. The method as recited in any one of claims 49-57, wherein monitoring the electrical probe includes monitoring a voltage differential or current flow between the electrical probe and a ground.

59. The method as recited in claim 58, wherein no external electrical signal is applied to the electrical probe, the voltage or current flow being generated by the electrical probe contacting the bulk material.

60. The method as recited in claim 58, wherein the ground is a reactor vessel of the polymerization reactor system.

61. The method as recited in any one of claims 49-60, further comprising detecting at least one other condition in the polymerization reactor system, wherein the determining the presence of condensate in the polymerization reactor system is based on the monitoring and the at least one other condition.

62. The method as recited in any one of claims 49-61, further comprising taking a remedial action for preventing formation of condensate.

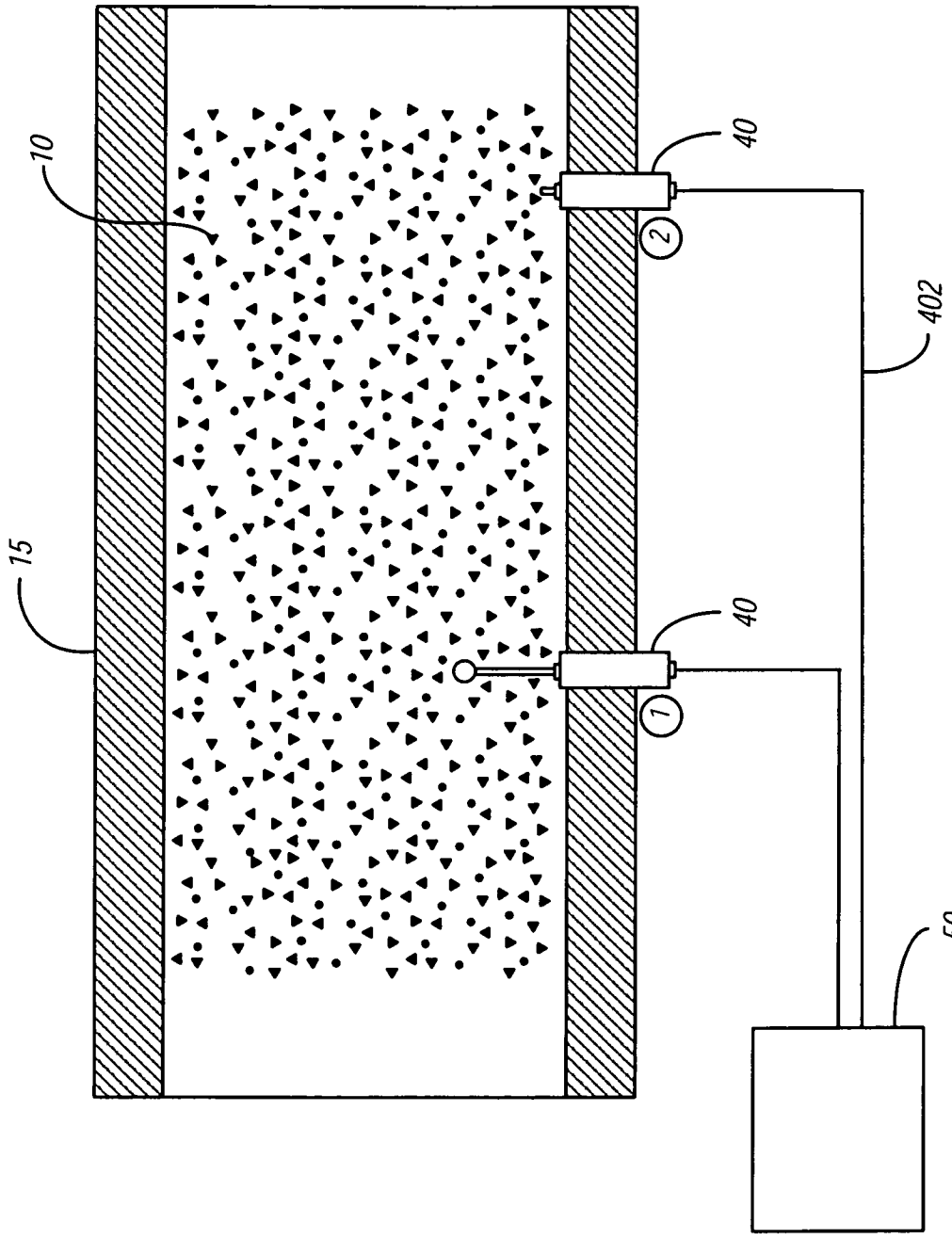


Figure 1

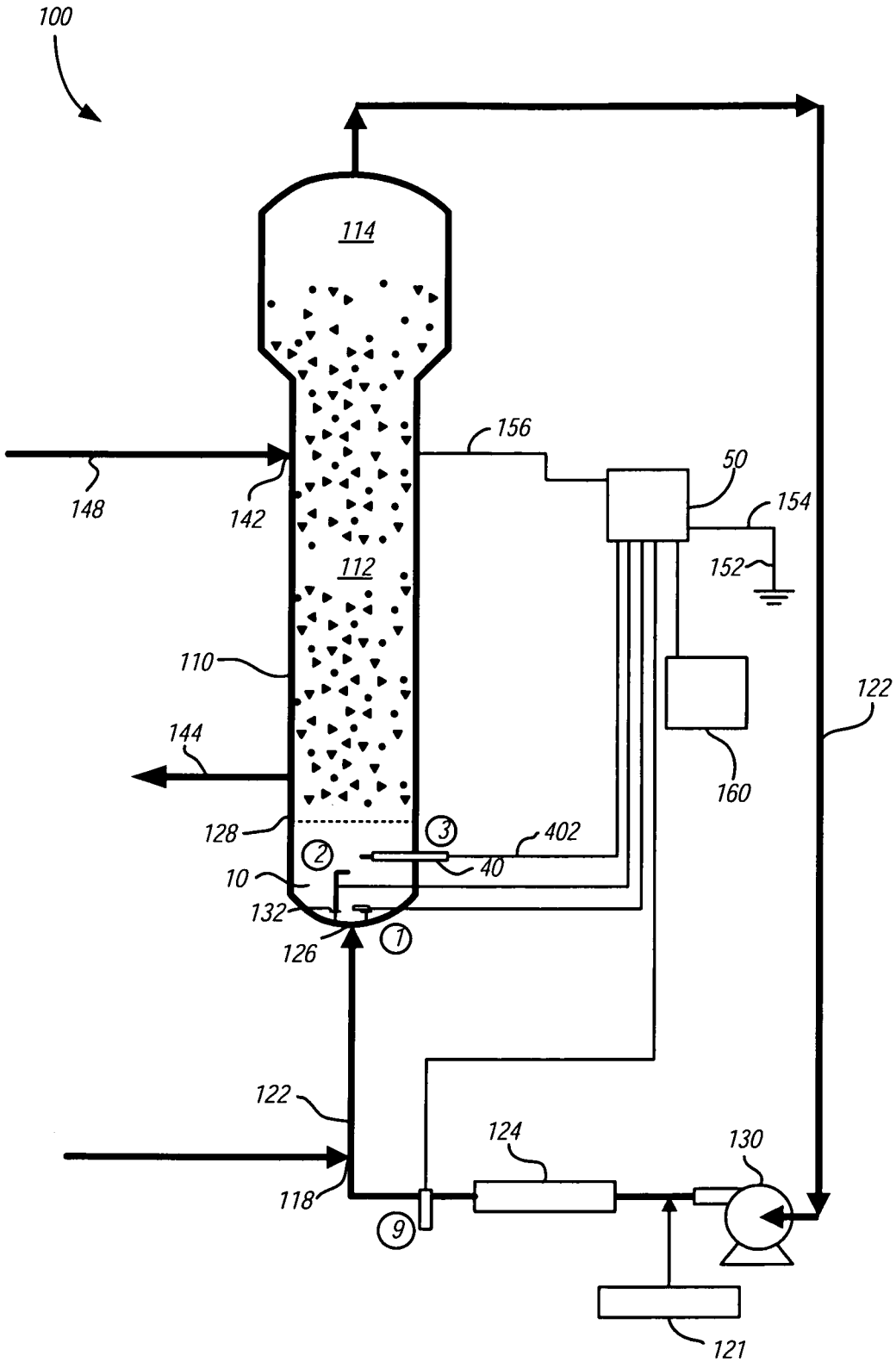

100
114
156
148
142
50
154
112
152
110
122
144
160
128
3
402
2
40
10
132
126
1
122
124
130
118
9
121

Figure 2

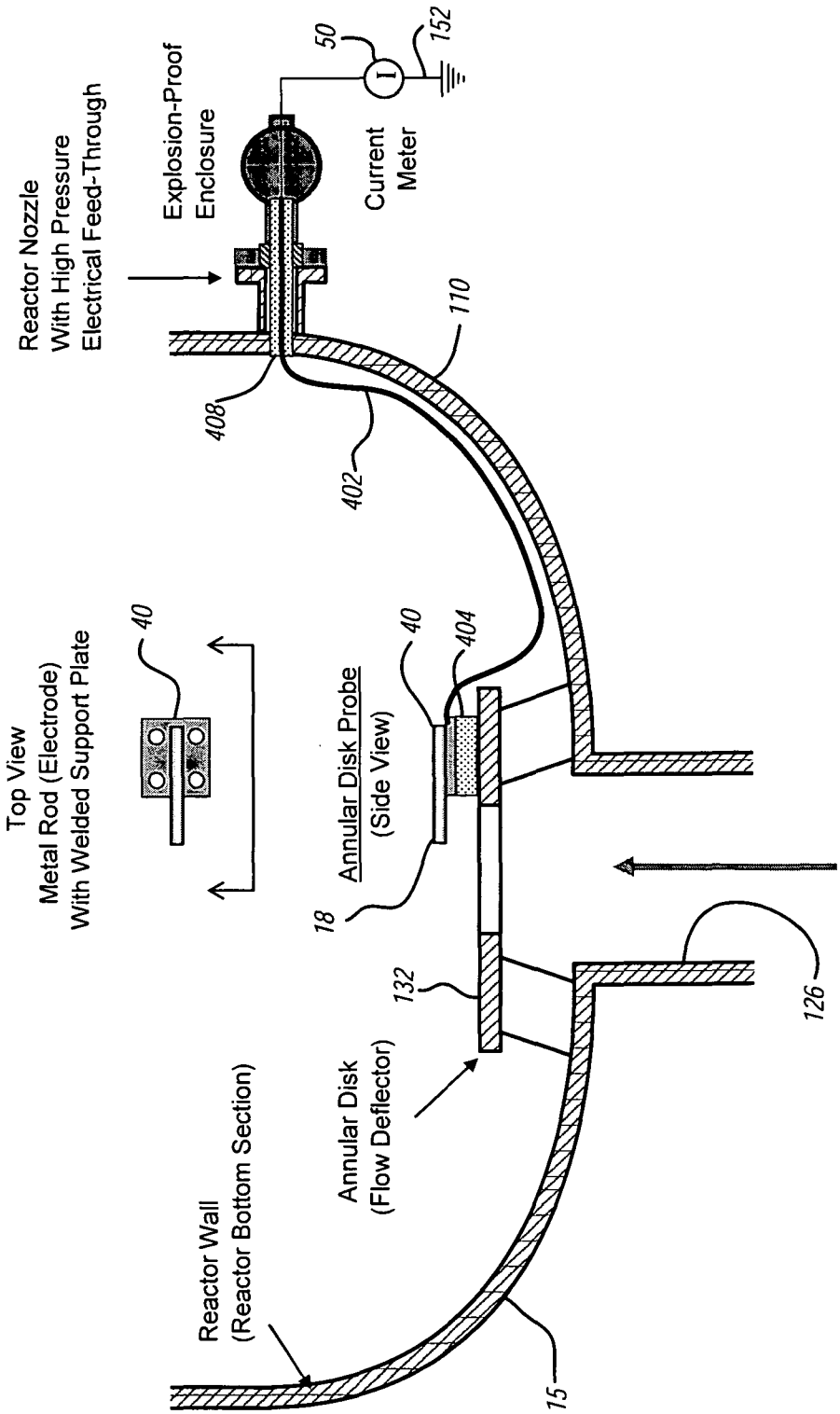

Reactor Nozzle
With High Pressure
Electrical Feed-Through
Explosion-Proof
Enclosure
Current
Meter
50
152
110
408
402
Top View
Metal Rod (Electrode)
With Welded Support Plate
40
Annular Disk Probe
(Side View)
40
404
18
132
Annular Disk
(Flow Deflector)
Reactor Wall
(Reactor Bottom Section)
15
126
Cycle Gas Stream
with Entrained Solids / Liquids

Figure 3

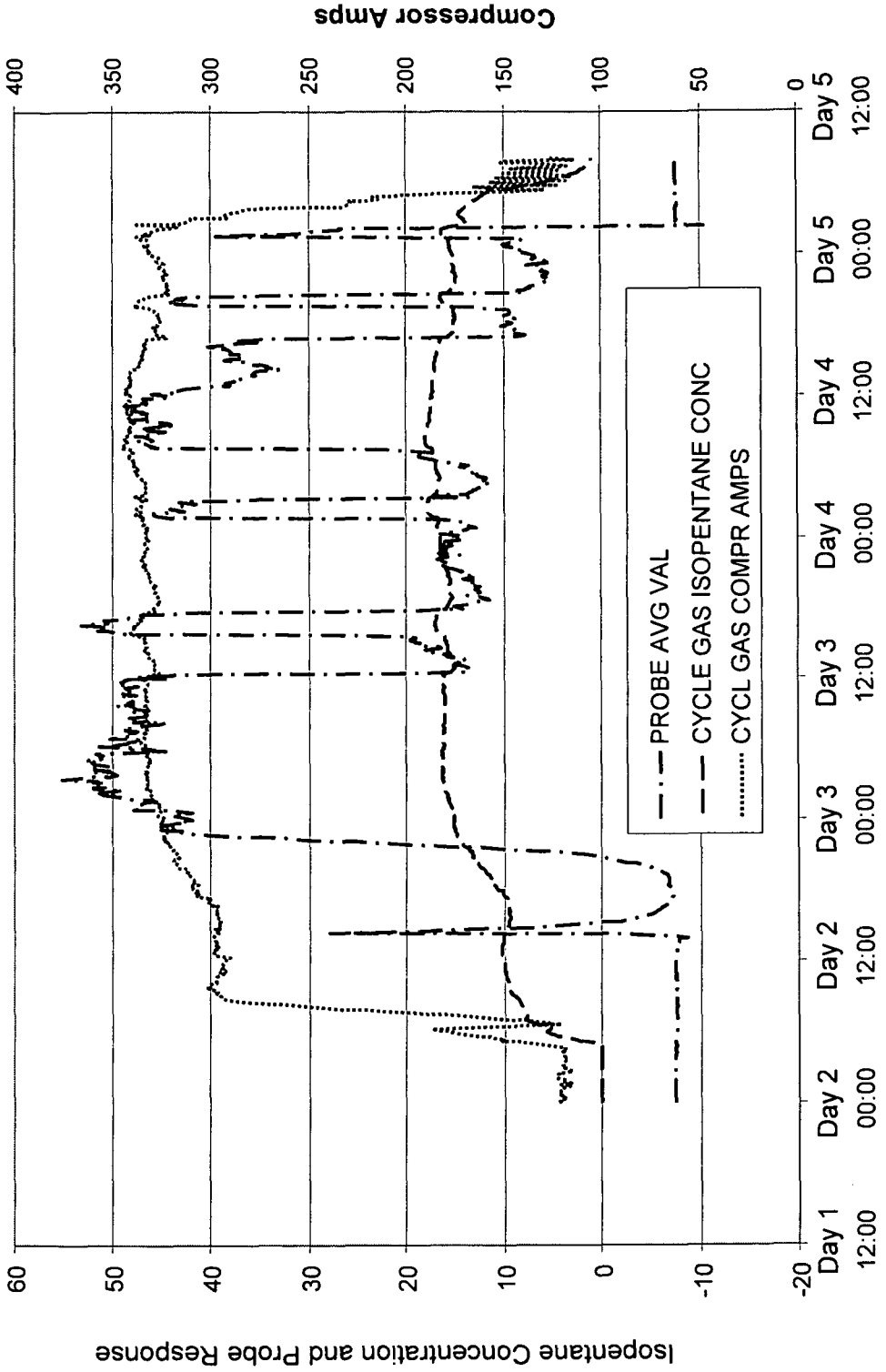

Compressor Amps
Isopentane Concentration and Probe Response
PROBE AVG VAL
CYCLE GAS ISOPENTANE CONC
CYCL GAS COMPR AMPS
Day 1 12:00
Day 2 00:00
Day 2 12:00
Day 3 00:00
Day 3 12:00
Day 4 00:00
Day 4 12:00
Day 5 00:00
Day 5 12:00
60
50
40
30
20
10
0
-10
-20
400
350
300
250
200
150
100
50
0

Figure 4

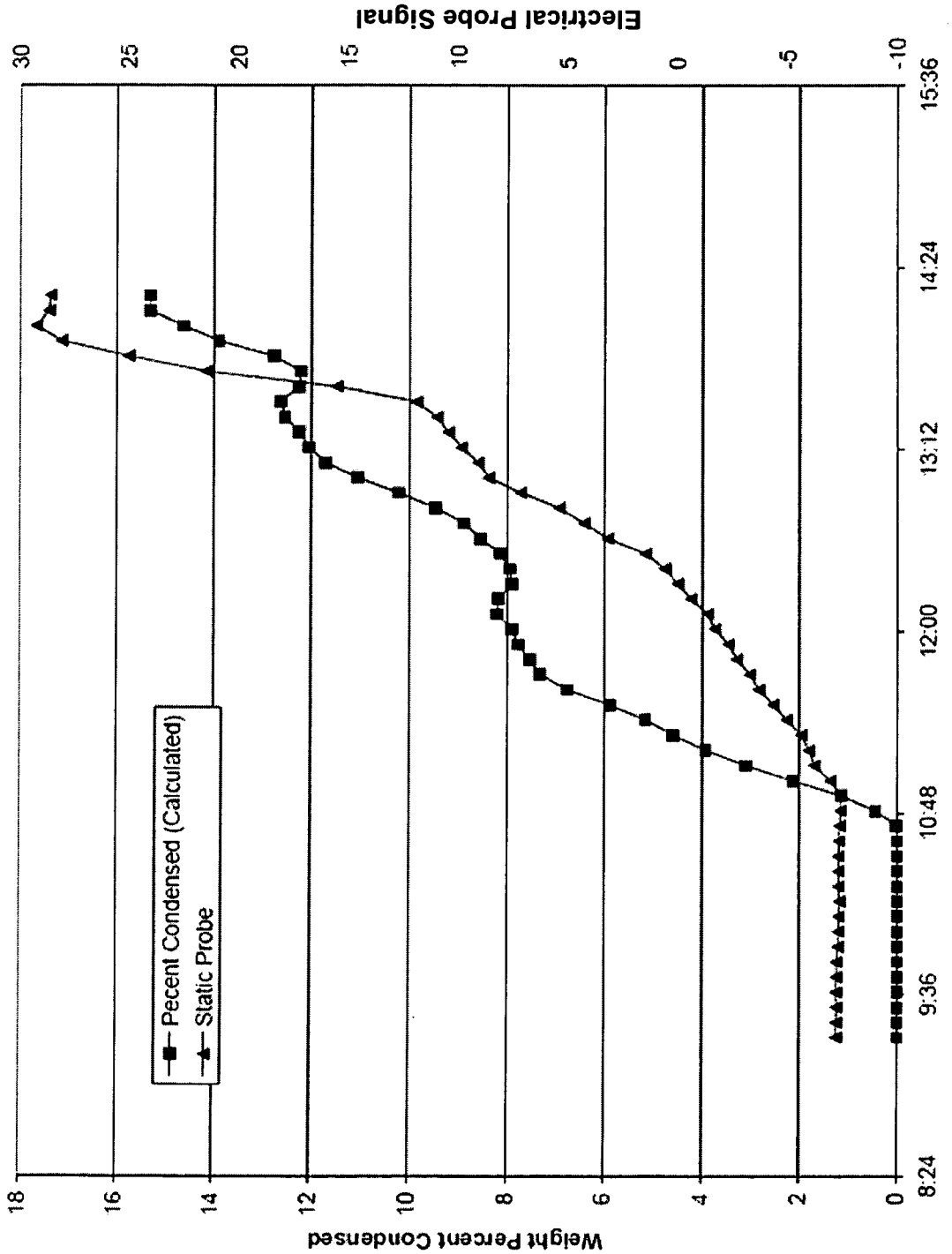

Electrical Probe Signal
30
25
20
15
10
5
0
-5
-10
Weight Percent Condensed
18
16
14
12
10
8
6
4
2
0
8:24
9:36
10:48
12:00
13:12
14:24
15:36
Time
Pecent Condensed (Calculated)
Static Probe

Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/013701

A. CLASSIFICATION OF SUBJECT MATTER
INV. C08F10/00 C08F2/34

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

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 practical, search terms used)
EPO-Internal, CHEM ABS Data, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/008169 A (UNIVATION TECH LLC [US]; MARKEL ERIC J [US]; HAGERTY ROBERT O [US]; MU) 17 January 2008 (2008-01-17) claims	1-62
A	US 2005/148742 A1 (HAGERTY ROBERT O [US] ET AL) 7 July 2005 (2005-07-07) paragraph [0097]; claims	1-62
A	US 2005/267268 A1 (HENDRICKSON GREGORY G [US]) 1 December 2005 (2005-12-01) cited in the application paragraph [0007]; claims	1-62
A	US 2001/024625 A1 (OLSON ROBERT DARRELL [US] ET AL) 27 September 2001 (2001-09-27) paragraph [0005]; claims	1-62

-/--

[X] Further documents are listed in the continuation of Box C.

[X] 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 document 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	Date of mailing of the international search report
7 April 2009	17/04/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016	Kaumann, Edgar

1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/013701

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 391 985 B1 (GOODE MARK GREGORY [US] ET AL) 21 May 2002 (2002-05-21) cited in the application claims	1-62

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2008/013701

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		AU 2004313933 A1	28-07-2005
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		EP 1699830 A1	13-09-2006
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		KR 20060117980 A	17-11-2006
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