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(71) Applicants: **IDEX MPT INC.** [US/US]; 90 Glacier Drive, Suite 1000, Westwood, Massachusetts, Massachusetts 02090 (US). **IDEX INDIA PVT. LTD.** [IN/IN]; A unit of IDEX Corporation, Survey No 256, GIDC Manjusr, Savli, Near Bombardier Circle, District – Vadodara, Gujarat 391775 (IN).

(72) Inventors: **SHAH, Anand**; C/o IDEX India Pvt. Ltd., Survey No 256, Near Bombardier Circle, GIDC Manjusr, Vadodara, Gujarat 391775 (IN). **BERNARD, John Michael**; C/o IDEX MPT Inc., 90 Glacier Drive, Suite 1000, Westwood, Massachusetts, Massachusetts 02090 (US). **VISHWAKARMA, Nilabh**; C/o IDEX India Pvt.

Ltd., Survey No 256, Near Bombardier Circle, GIDC Manjusr, Vadodara, Gujarat 391775 (IN). **KHARCHE, Rahul**; C/o IDEX India Pvt. Ltd., Survey No 256, Near Bombardier Circle, GIDC Manjusr, Vadodara, Gujarat 391775 (IN). **CATALANI, Marco**; C/o IDEX MPT Inc., 90 Glacier Drive, Suite 1000, Westwood, Massachusetts, Massachusetts 02090 (US). **VYAS, Jimit**; C/o IDEX India Pvt. Ltd., Survey No 256, Near Bombardier Circle, GIDC Manjusr, Vadodara, Gujarat 391775 (IN). **SINGH, Daljit**; C/o IDEX India Pvt. Ltd., Survey No 256, Near Bombardier Circle, GIDC Manjusr, Vadodara, Gujarat 391775 (IN). **MAHALATKAR, Kartikeya**; C/o IDEX India Pvt. Ltd., Survey No 256, Near Bombardier Circle, GIDC Manjusr, Vadodara, Gujarat 391775 (IN). **MODI, Mihir**; C/o IDEX India Pvt. Ltd., Survey No 256, Near Bombardier Circle, GIDC Manjusr, Vadodara, Gujarat 391775 (IN). **HARNEY, David**; C/o IDEX MPT Inc., 90 Glacier Drive, Suite 1000, Westwood, Massachusetts, Massachusetts 02090 (US). **RATIGAN, Michael**; C/o IDEX MPT Inc., 90 Glacier Drive, Suite 1000, Westwood, Massachusetts, Massachusetts 02090 (US). **RAMINA, Joe**; C/o IDEX MPT Inc., 90 Glacier Drive, Suite 1000, Westwood, Massachusetts, Massachusetts 02090 (US).

(54) Title: HOMOGENIZER WITH FIXED GEOMETRY MICROFLUIDIC CHAMBERS WITH A HIGH PRESSURE MULTI-PLEX PUMPING SYSTEM

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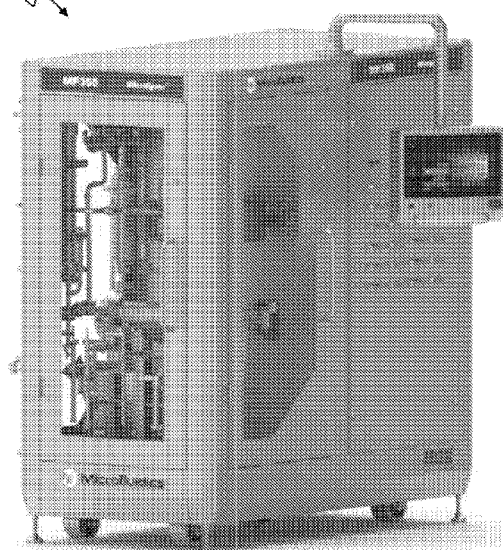


Fig. 1B

(57) Abstract: The present invention introduces a homogenizer apparatus (100) designed to optimize fluid processing. Central to the apparatus is a high-pressure plunger pump equipped with a plurality of cylinders (104), each receiving fluid propelled by a reciprocating motion of one or more high strength wear-resistant material ceramic plungers (106) made from high-strength, wear-resistant materials. This setup is complemented by low and high-pressure seals (118, 124), a ceramic bearing (122), and an U-cup seal (126) to ensure enhanced durability and minimize contamination risks. A pneumatic or electrically operated feed pump, specifically an Air-Operated Double Diaphragm (AODD) Pump, or an Electrically driven pump is incorporated which facilitates efficient fluid charging into the high-pressure plunger pump. The apparatus includes a microfluidic interaction chamber (204) with orifices of fixed geometry, crafted from wear-resistant materials. The system's efficiency is further augmented by the integration of integrated check valves, providing an alternate flow path configuration. The apparatus is also including bellows and a partition wall, for structural integrity and reduce vibration-induced wear and facilitate zonal separation within the apparatus. This design enhances operational safety and efficiency, making the homogenizer apparatus particularly suitable for high-pressure applications requiring precise control over fluid processing parameters.

(74) **Agent: MAHUA RAY**; Remfry & Sagar, Attorneys-at-law,
Remfry House at the Millennium Plaza, Sector 27, Gurgaon,
Haryana 122 009 (IN).

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HOMOGENIZER WITH FIXED GEOMETRY MICROFLUIDIC CHAMBERS WITH A HIGH PRESSURE MULTIPLEX PUMPING SYSTEM

FIELD OF INVENTION

[0001] The present invention relates to the field of pumping devices, and more particularly to a multiplex pumping apparatus for processing of fluids.

BACKGROUND OF THE INVENTION

[0002] The subject matter discussed in the background section should not be assumed to be prior art merely because of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in and of themselves may correspond to implementations of the claimed technology.

[0003] In high-pressure fluid processing for applications such as cell disruption, homogenization, nano-emulsification, particle size reduction, chemical mixing, high shear processing, etc., a high pressure pumping device of a sanitary nature in design and construction is required. The pumping device is utilized in chemical processing, food processing, pharmaceutical applications, and biotechnology operations. The pumping device includes pumps, such as, single intensifier pumps, dual intensifier pumps, triplex pumps, and multiplex pumping systems, etc. capable of operating at a high pressure up to 340 MPa (50,000 psi). The applications of the high pressure pumping device generally involve generation of a shearing action in a fluid, with the help of high pressure.

[0004] The pumping devices that are often used for a variety of pharmaceutical applications, which involves pumping a biological fluid at high pressure into microfluidic interaction chambers having small orifices to cause the shearing action in the biological fluid. However, such pumping device typically include components that are easily contaminated by the biological fluid. Such components are often required to be frequently replaced for optimal operation of the pumping device, since use of such components may lead to contamination of the biological fluid. This limits functionality of the pumping device for repeated use, and increases the risk of contamination of the biological fluid. Also, such pumping devices are not

suitable for high-pressure applications, since frequent breakdown occurs due to frequent flow and pressure variations in a discharge line of the fluid. This severely affects reliability and availability, and increases maintenance cost.

[0005] The realm of fluid processing, especially in sectors such as pharmaceuticals, biotechnology, chemical processing, and food processing, demands equipment capable of operating under high-pressure conditions to achieve desired outcomes like cell disruption, homogenization, nano-emulsification, particle size reduction, and high shear mixing. Traditional pumping devices, while functional, often fall short in meeting the comprehensive needs of these applications due to limitations in durability, contamination risk, and operational efficiency under varying pressures.

[0006] Historically, the industry has relied on a range of pumping systems, including single and dual intensifier pumps, triplex, or multiplex pumping systems. Despite their capabilities, these systems frequently encounter challenges related to component wear and contamination, necessitating frequent maintenance or part replacement that can interrupt process continuity and increase operational costs. Furthermore, the complexity and rigid design of these systems often complicate maintenance procedures and limit their adaptability to various processing conditions.

[0007] Current pharmaceutical homogenizers using intensifier pumps which consists of a hydraulic system and PLC controls to boost the pressure of process fluid and are complex as well as expensive. Some other pharma homogenizers use a triplex pumping system with a valve which is observing a very high-pressure differential across it leading to wear as well as low life / reliability/frequent break down. The present inventions combine a robust and simple triplex pump with a Microfluidics interaction chamber which mixes the low complexity of Triplex/Multiplex pumping system with the high reliability of the microfluidic interaction chamber to process high pressure differential for cell rupture.

[0008] Another significant issue has been the inefficient separation and control of processing zones within these apparatuses, leading to heightened risks of cross-contamination between different fluid types or between processing stages. This issue is particularly critical in applications involving sensitive biological fluids, where maintaining strict environmental controls is paramount to ensure product integrity and safety.

[0009] In light of these challenges, there exists a substantial need for an innovative solution capable of addressing the limitations of existing high-pressure fluid processing

equipment. Such a solution should offer enhanced durability, ease of maintenance, adaptable operation under varying pressure conditions, and improved contamination control mechanisms, all while ensuring high processing efficiency and reliability.

[0010] In view of the above-mentioned shortcomings, there arises a need to provide a multiplex pumping apparatus for fluid processing in high-pressure applications.

OBJECTS OF THE INVENTION

[0011] An object of the present invention is to provide a simplified and low-cost multiplex pumping apparatus for processing of fluids in high-pressure applications, capable of achieving precise control over operating pressure of the fluid to be processed.

[0012] Another object of the present invention is to provide a multiplex pumping apparatus with increased efficiency and reliability.

[0013] Another object of the present invention is to provide a sanitary pumping apparatus capable of reducing the risk of biological contamination of the fluid to be processed.

[0014] Another object of the present invention is to facilitate easy maintenance and enhance operational longevity by incorporating a system of external check valves designed for modularity of part replacement, allowing for independent replacement without necessitating disassembly or replacement of other components.

[0015] Another object of the present invention is to improve the safety and contamination control within the homogenizer apparatus by introducing a bellows and partition wall configuration that effectively segregates high-pressure zones from lower-pressure zones, and further, to delineate operational areas into red and green zones based on contamination risk, thereby ensuring a safer and more controlled processing environment.

[0016] A further object of the present invention is to optimize the fluid processing operation by integrating a microfluidic interaction chamber with fixed geometry orifices made of wear-resistant material, in conjunction with a high-pressure plunger pump, to significantly reduce fluid processing time while achieving superior process results.

SUMMARY OF THE INVENTION

[0017] The summary is provided to introduce aspects related to a multiplex pumping apparatus, and the aspects are further described below in the detailed description. This

summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining or limiting the scope of the claimed subject matter.

[0018] The multiplex pumping apparatus (also referred to as “homogenizer” hereinafter) includes a high-pressure triplex plunger pump having a plurality of external check valves vertical arranged with each other, and a microfluidic interaction chamber configured to mix and impinge the fluid and generate high shear in the fluid to produce a proceed fluid. The microfluidic interaction chambers may include a single orifice or multiple orifices having fixed geometry. The orifices may be made of a hard material to resist wear and tear. Such as diamond, ceramic, Tungsten carbide etc. The plunger pump may be operated at higher pressures to reduce fluid processing time and achieve better process results with the microfluidic interaction chambers.

[0019] In a preferred embodiment, the present invention provides a homogenizer apparatus for fluid processing, comprising: a high-pressure plunger pump with a plurality of cylinders, each cylinder receiving fluid pumped by a reciprocating motion of one or more high-strength wear-resistant material like ceramic plungers, and housed within a mounting block aligned for high-pressure applications; a low and high-pressure seals within each cylinder, along with a ceramic bearing and an U-cup seal to enhance durability and reduce contamination risks; a drive unit, such as a motor, connected to the plungers via driveline and fluid side couplings to enable their reciprocating motion; a plurality of external check valves vertically arranged in relation to the cylinders, each valve being one-way spring-loaded to facilitate the development of high pressure for fluid processing and each of the plurality of external check valves includes an elongated stem with a spring-loaded member and O-rings for tight sealing, and a cap designed to rest on an inner race of a bearing, enhancing the valve's functionality under high pressure, wherein the plurality of external check valves are arranged for modularity of part replacement, allowing for the independent replacement of any one valve without necessitating the disassembly or replacement of other valves, thereby improving maintenance efficiency and reducing downtime; a microfluidic interaction chamber integrated with the high-pressure plunger pump, featuring orifices with fixed geometry made of wear-resistant material for effective mixing and shearing of the fluid under high pressure and the chamber operates in conjunction with the high-pressure pump to reduce fluid processing time and improve process results; a priming valve within high pressure piping, specifically added for priming purposes, to ensure the chamber and the high-pressure plunger pump are appropriately filled and free of air pockets, thus enhancing the efficiency and reliability of fluid processing; a control and data

acquisition unit for monitoring and controlling temperature, pressure, and flow rate of the fluid, and for collecting data from sensors located near the cylinders, plungers, and check valves; a variable frequency electronic drive coupled with the drive unit, facilitating precise control of fluid pressure through the homogenizer; a pneumatic or electrically operated feed pump, for charging the fluid into the high-pressure plunger pump and the diaphragm of the pneumatic or electrically operated feed pump facilitates a reciprocating motion to pump the fluid efficiently and is configured to work in tandem with the drive unit to enhance the charging process and ensure consistent fluid supply to the cylinders; a bellows and a partition wall arranged to encapsulate the plurality of external check valves, enhancing structural integrity and minimizing vibration-induced wear wherein the bellows are arranged within external check valves to accommodate the thermal and pressure-induced expansions and contractions, ensuring a leak-proof and durable connection between the external check valves and the high-pressure system and the partition wall segregate the high-pressure zones from lower-pressure zones within the apparatus enhancing the operational safety and efficiency of the homogenizer.

[0020] In an embodiment, wherein each of the high strength wear resistant material like ceramic plungers is configured to withstand high temperature and pressure conditions for enhanced processing efficiency.

[0021] In an embodiment, wherein the low and high-pressure seals in each cylinder are U-cup seals, specifically designed for maintaining high-pressure integrity.

[0022] In an embodiment, wherein the external check valves are configured with O-rings (308) made of a material resistant to chemical corrosion and high temperature.

[0023] In an embodiment, wherein the external check valves are an integrated valve which may be a suction check valves, a tee, and a discharge check valve, providing an alternate flow path configuration to enhance the fluid dynamic efficiency and flexibility in pressure management within the high pressure plunger pump.

[0024] In an embodiment, wherein the pneumatic operated feed pump is an air-operated double diaphragm feed (AODD) pump or wherein electrically operated feed pump is an electrically driven pump to feed the pumping apparatus.

[0025] In an embodiment, comprising a heat exchanger connected downstream of the microfluidic interaction chamber for regulating the temperature of the processed fluid.

[0026] In an embodiment, wherein the control and data acquisition unit are configured to adjust the variable frequency electronic drive based on real-time data from the temperature and pressure sensors.

[0027] In an embodiment, wherein the microfluidic interaction chamber is configured to handle multiple types of fluids, including biological fluids and chemicals, without risk of cross-contamination.

[0028] In an embodiment, wherein the variable frequency electronic drive includes a Proportional-Integral-Derivative (PID) controller for refined control over the drive unit's speed and torque.

[0029] In an embodiment, wherein the mounting block includes a fork for accurate alignment of the cylinders, facilitating high-precision fluid processing.

[0030] In an embodiment, wherein the bellows and partition wall provide a barrier to separate the apparatus into a red zone and a green zone, with the red zone designated for high contamination risk operations and the green zone for operations with lower contamination risk, thereby enhancing safety and contamination control within the homogenizer apparatus.

[0031] In another aspect of the present invention, a method for processing fluids using a homogenizer apparatus, comprising: pumping fluid into a high-pressure plunger pump of the homogenizer, which includes a plurality of cylinders, each cylinder receiving the fluid pumped by a reciprocating motion of one or more high strength wear-resistant materials like ceramic plungers within a mounting block aligned for high-pressure applications; ensuring durability and contamination prevention by maintaining fluid within low and high-pressure seals in each cylinder, supported by a ceramic bearing and an U-cup seal; driving the high strength wear-resistant material like ceramic plungers in a reciprocating motion using a drive unit, such as a motor, connected via driveline and fluid side couplings; developing high pressure for fluid processing by passing the fluid through a plurality of vertically arranged external check valves, each being one-way spring-loaded and comprising an elongated stem with a spring-loaded member and O-rings for tight sealing, and a cap resting on an inner race of a bearing to enhance valve functionality under high pressure. This includes the integration of integrated check valves, comprising suction check valves, a tee, and a discharge check valve, to provide an alternate flow path configuration for enhanced fluid dynamic efficiency and pressure management flexibility; priming the high-pressure system and the microfluidic interaction chamber before processing begins to ensure the chamber and system are properly filled and

free of air pockets, utilizing a specifically added priming valve for this purpose, thus enhancing processing efficiency and reliability; mixing and shearing the fluid in the microfluidic interaction chamber integrated with the high-pressure plunger pump, where the chamber features orifices with fixed geometry made of wear-resistant material. The chamber's operation is aligned to reduce fluid processing time and improve process results; monitoring and controlling the temperature, pressure, and flow rate of the fluid during processing, utilizing a control and data acquisition unit that collects data from sensors located near the cylinders, plungers, and check valves; precisely controlling the fluid pressure throughout the homogenizer process using a variable frequency electronic drive coupled with the drive unit; charging the fluid into the high-pressure plunger pump using a pneumatic or electrically operated feed pump, specifically an air-operated double diaphragm feed pump or an electrically driven pump. The diaphragm of the feed pump facilitates a reciprocating motion to pump the fluid efficiently and is configured to work in tandem with the drive unit to enhance the charging process and ensure consistent fluid supply to the cylinders; implementing bellows and a partition wall in conjunction with the external check valves to provide mechanical flexibility and isolation, respectively, wherein the partition wall and bellows arrangement effectively separates operational zones within the homogenizer apparatus, enhancing structural integrity and operational isolation between different processing stages.

[0032] In an embodiment, including the step of adjusting the reciprocating motion of the high strength wear resistant material like ceramic plungers based on the fluid type and processing requirements.

[0033] In an embodiment, wherein controlling the temperature, pressure, and flow rate includes using a PID controller to adjust the variable frequency electronic drive in response to sensor data.

[0034] In an embodiment, comprising the step of cooling the processed fluid using a heat exchanger immediately after it exits the microfluidic interaction chamber.

[0035] In an embodiment, wherein the processing of the fluid is adapted based on the fluid type, including adjustments for biological fluids and chemical mixtures.

[0036] In an embodiment, including performing SIP operations using saturated steam or CIP operations typically done with chemicals and detergents to ensure the sanitization and sterility of the homogenizer.

[0037] In an embodiment, including the step of calibrating the control and data acquisition unit to optimize processing parameters for different fluid types.

[0038] In an embodiment, wherein the processing includes adjusting the operation of the external check valves to manage the pressure build-up during high-pressure fluid processing.

[0039] In an embodiment, involving the step of utilizing the fork in the mounting block for precise alignment and calibration of the cylinders in the high-pressure plunger pump.

[0040] In an embodiment, wherein the fluid processing is tailored for specific applications such as emulsification, suspension, particle size reduction, dispersing, or dissolving of various fluids.

[0041] In an embodiment, including creating a barrier with bellows and partition wall to separate the homogenizer apparatus into a red zone and a green zone, where the red zone is designated for high contamination risk operations and the green zone for operations with lower contamination risk, thereby enhancing safety and contamination control during the fluid processing.

BRIEF DESCRIPTION OF ACCOMPANYING DRAWINGS

[0042] The accompanying drawings constitute a part of the description and are used to provide a further understanding of the present invention. Such accompanying drawings illustrate the embodiments of the present invention used to describe the principles of the present invention. The embodiments are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which references indicate similar elements. It should be noted that references to “an” or “one” embodiment in this invention are not necessarily to the same embodiment, and they mean at least one. In the drawings:

[0043] **Figs. 1A and 1B** illustrate various representations of a multiplex pumping apparatus, in accordance with an embodiment of the present invention;

[0044] **Figs. 2A to 2D** illustrate perspective views of vertical arrangement of a plurality of external valves of the multiplex pumping apparatus, in accordance with an embodiment of the present invention;

[0045] **Fig. 3** illustrates an exploded view of the external check valve in accordance with an embodiment of the present invention;

[0046] **Fig. 4** illustrates a schematic representation of operation of the multiplex pumping apparatus in accordance with an embodiment of the present invention;

[0047] **Fig. 5** illustrates an exploded view showing various components of the multiplex pumping apparatus in accordance with an embodiment of the present invention; and

[0048] **Fig. 6** illustrates a flow chart depicting piping and instrumentation diagram (P&ID) of the multiplex pumping apparatus, in accordance with an embodiment of the present invention.

[0049] **Fig. 7** illustrates a pneumatic or electrically operated feed pump which may be an Air-Operated Double Diaphragm (AODD) Pump or Electrically Driven pump of the multiplex pumping apparatus in accordance with an embodiment of the present invention.

[0050] **Fig. 8** illustrates a Priming Valve, of the multiplex pumping apparatus in accordance with an embodiment of the present invention.

[0051] **Fig. 9** illustrates a Integrated Check Valves, of the multiplex pumping apparatus in accordance with an embodiment of the present invention.

[0052] **Fig. 10** illustrates the separation into Green Zone and Red Zone within the multiplex pumping apparatus in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0053] The detailed description set forth below in connection with the appended drawings is intended as a description of various embodiments of the present invention and is not intended to represent the only embodiments in which the present invention may be practiced. Each embodiment described in this disclosure is provided merely as an example or illustration of the present invention and should not necessarily be construed as preferred or advantageous over other embodiments. The detailed description includes specific details for the purpose of providing a thorough understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced without these specific details.

[0054] As used in the description herein and throughout the claims that follow, the meaning of “a,” “an,” and “the” includes plural reference unless the context clearly dictates otherwise. In addition, as used in the description herein, the meaning of “in” includes “in” and “on” unless the context clearly dictates otherwise.

[0055] The terms “or” and “and/or” as used herein are to be interpreted as inclusive or meaning any one or any combination. Therefore, “A, B or C” or “A, B and/or C” mean “any of the following: A; B; C; A and B; A and C; B and C; A, B and C.” An exception to this definition will occur only when a combination of elements, functions, steps or acts are in some way inherently mutually exclusive.

[0056] The present invention relates to a simplified multiplex pumping apparatus (also referred to as “homogenizer” hereinafter) for processing of fluids. The pumping apparatus is capable of processing the fluid for high-pressure applications, while precisely controlling process variables such as temperature, pressure, and flow of the fluid, to improve reliability and product yield characteristics of the pumping apparatus. The pumping apparatus is compact and includes components having simple configurations, thereby improving reparability and availability thereof. The multiplex pumping apparatus may be used with high pressure homogenizers for processing of biological fluids, and may include any of a single intensifier pump, a dual intensifier pump, a triplex pump, etc. capable of operating at pressures up to 50,000 psi in both industrial and pharmaceutical applications.

[0057] **Figures 1A and 1B** illustrate various representations of a multiplex pumping apparatus (also referred to as a “homogenizer” hereinafter) **100** which includes a high pressure pumping system. The high pressure pumping system includes a positive displacement plunger pump driven by a variable frequency electronic drive to accurately control pressure of the fluid passing therethrough. The variable frequency electronic drive may be coupled with a drive unit **102**, such as, a motor, using belt and pulley arrangements. The plunger pump may receive the fluid from a feed pump. The plunger pump may be constructed of high temperature materials that allow its internal surfaces to be steamed, to achieve the necessary sanitization or sterilization temperatures for efficient cleaning and drainage thereof. The homogenizer **100** includes a plurality of cylinders **104** configured to receive the fluid pumped by reciprocating motion of one or more plungers **106** of the plunger pump driven by the drive unit **102**. Multiple cylinders **104** may be fitted into a mounting block **108** acting as a housing for the cylinders **104**. A fork **110** is provided to make accurate alignment of the cylinders **104** with the mounting block **108** with precision tolerances for high-pressure applications. The fork **110** may be mounted and aligned with the drive unit **102** with the help of fasteners **112**, such as, bolts, pins or dowels. The mounting block **108** is placed on fork **110** with the help of locating fasteners **114** coupled with fork **110**.

[0058] The high pressure cylinder **104** includes an end cap **116**, low pressure seals **118**, spacer **120**, ceramic bearing **122**, high pressure seal **124** and O-ring seal **126**. The low pressure seals **118** and the high pressure seal **124** may be U-cup seals. The high pressure seal **124** is installed with a U-cup seal installation tool, and then the ceramic bearing **122** is inserted into the cylinder **104**. Thereafter, the low pressure seal **118** is placed in a groove of the end cap **116**. The spacer **120** is fitted in the end cap **116**, and fastened with a set of fasteners. The cylinder **104** thus formed is slide into the mounting block **108** and fastened. The high strength wear-resistant material like ceramic plunger **106** is placed in the cylinder **104**. A driveline side coupling **126** is fastened to a pony rod of the drive unit **102** using a fastener **128**. A fluid side coupling **130** is engaged with the driveline side coupling **126**. The high strength wear-resistant material like ceramic plunger **106** is connected with the fluid side coupling **130**, to enable reciprocating motion of plunger **106** by rotation of the driveline side coupling **126**.

[0059] Referring now to Figures **2A** and **2D**, the positive displacement plunger pump utilizes a plurality of external check valves **202** vertical arranged with each other, and an microfluidic interaction chamber **204**, as shown in **Fig. 5**, to mix and impinge the fluid and generate high shear in the fluid to produce a processed fluid. The microfluidic interaction chambers **204** may include a single orifice or multiple orifices having fixed geometry. The orifices may be made of a hard material to resist wear and tear. The plunger pump may be operated at higher pressures to reduce fluid processing time and achieve better process results with the microfluidic interaction chambers **204**. The pumping apparatus **100** also includes a control and data acquisition unit configured to acquire and collect data from the temperature and pressure sensors disposed in vicinity of the cylinder **104**, plungers **106**, etc. The control and data acquisition unit is also configured to control process variables, such as, flow and temperature characteristics of the fluid to be supplied to the plunger pump.

[0060] The vertical arranged external check valves **202** may include one-way spring loaded check valves to help develop high pressure needed for efficient processing of the fluid. The vertical arrangement of the external check valves **202** also contribute to easy drainability of any residual matter. The multiplex plunger pump is capable of operating at high pressure pump of the order of 2 to 250 MPa (300 to 50,000 psi). The multiplex plunger pump is integrated with the fixed geometry microfluidic interaction chambers **204** to produce high shear necessary for fluid processing.

[0061] **Figure 3** illustrates a plunger assembly **302**. The plunger assembly **302** is designed to facilitate development of high pressure needed for efficient processing of the fluid by

creating precise pressure differentials within the system. The plunger assembly **302** includes an elongated stem **304** provided in a casing **306**. The elongated stem **304** is provided with a spring-loaded member **308** which adds resilience and assists in the movement of the plunger. The spring-loaded member **308** is crucial for maintaining consistent pressure and facilitating smooth operation. Ends of the spring loaded member **308** may be fitted with O-rings **310** encircling the elongated stem **302** to ensure a tight seal for preventing any leakage of fluid or stream along the length of the assembly. The elongated stem **304** includes a cap **312** adapted to rest on an inner race of a bearing **314**, when the elongated stem **304** is installed in the casing **306**. Another O-ring **316** may be used to prevent any leakage of the fluid or steam from the interface between the cap **312** and the bearing **314**. The plunger assembly **302** is vertically arranged to improve drain ability of residual matters present in the fluid or the steam.

[0062] **Figure 4** illustrates a schematic representation of operation of the multiplex pumping apparatus **100**. The fluid to be processed, stored in a feed tank **402**, may be pumped by a feed pump **404**, as clearly shown in **Figure 5**, to a sanitary region of the plunger pump. The plunger pump may be driven by a variable frequency electronic drive to accurately control pressure of the fluid passing therethrough. The variable frequency electronic drive may be coupled with the drive unit **102** using belt and pulley arrangements. The drive unit **102** may include a motor having Variable Frequency Drive (VFD) **406** for regulating speed and torque of an output shaft thereof, by varying frequency of an input electric voltage. The VFD **406** may be controlled by a Proportional-Integral-Derivative (PID) controller **408**. The PID controller **408** may be configured to regulate speed of the drive unit **102** based on operating pressure of the fluid to be processed, to enable efficient control over pressure of the fluid passing to the microfluidic interaction chambers **204**. Referring to Fig. 5, the PID controller **408** may be interfaced with a computing device **504**, such as, an industrial personal computer, a laptop, a portable device, etc., to allow a user to provide input and control input parameters of the VFD **406**.

[0063] The fluid pumped by the plunger pump may be conveyed to the microfluidic interaction chambers **204** configured to mix and impinge the fluid and generate high shear in the fluid to produce the processed fluid. The fluid pumped by the plunger pump flows to the microfluidic interaction chambers **204** through the high pressure cylinders **104**. The processed fluid then passes to a heat exchanger **412**, as shown in **Figure 5**, adapted to efficiently regulate temperature of the fluid, thereby obtaining a better quality of processed fluid. Thereafter, the processed fluid automatically flows to a collection tank **414** for further processing or usage

therefor. Also, temperature sensors, pressure sensors and flow sensors may be arranged throughout the multiplex pumping apparatus **100** to detect temperature and pressure of various components thereof. As shown in **Fig. 4**, a pressure sensor **P1** may be disposed in vicinity of the cylinder **104** or plungers **106** of the plunger pump to detect pressure values of the cylinder **104** or the plungers **106**. A temperature sensor **T1** and a pressure sensor **P2** may be located at piping or conduits between the feed pump **404** and the plunger pump to detect instantaneous temperature and pressure values of the piping.

[0064] **Figure 6** illustrates a flow chart depicting piping and instrumentation diagram (P&ID) of the multiplex pumping apparatus **100** is shown. The homogenizer **100** may include a piping architecture **502**, as show in **Fig. 5**, to provide a passage for flow of the fluid to various components, while allowing Steaming-in-Place (SIP) using a saturated steam or Cleaning-in-Place (CIP) typically done with detergents and chemicals. The piping architecture may employ a plurality of flow control valves, such as, check valves, ball valves, diaphragm valves, needle valves, etc., to efficiently regulate flow of the fluid and the steam. The fluid to be processed may be provided at an inlet of the piping architecture. Subsequently, the steam may be passed to the inlet, through a ball valve, to prevent reverse flow thereof. The steam passing through the piping architecture may be drained through drain pipes.

[0065] The piping architecture may also include flow regulators and steam regulators configured to restrict and reduce the amount of fluid and the steam flowing through respective pipes of the piping architecture. Steam traps may be appropriately arranged in the piping architecture to discharge condensates and non-condensable gases present in the steam. Temperature and pressure sensors are also arranged throughout the piping architecture to detect temperature and pressure of respective pipes or conduits. The control and data acquisition unit acquire and collects data from the temperature and pressure sensors located throughout the piping architecture to efficiently control the process variables of the multiplex pumping system.

[0066] **Figure 7** illustrates a Pneumatic Operated Feed Pump or electrically operated feed pump in the Homogenizer Apparatus. In an embodiment of the present invention of **Fig. 7** discloses a pneumatic operated feed pump, exemplified by an Air-Operated Double Diaphragm (AODD) Pump, or electrically operated pump which is integral for optimizing the charging process of fluids into a high-pressure plunger pump. The integration of the pneumatic operated feed pump or electrically operated feed pump, such as an AODD or electrically driven Pump, presents a solution to the challenges faced by Traditional fluid charging methods by offering reliable and efficient fluid transfer under varying operational conditions. Referring to **Figure 7**,

the embodiment illustrates a pneumatic or electrically operated feed pump, specifically an Air-Operated Double Diaphragm (AODD) Pump or Electrically Driven Pump, as employed in a homogenizer apparatus (100) designed for fluid processing. This feed pump plays a pivotal role in charging fluid into the high-pressure plunger pump, which constitutes a core component of the homogenizer apparatus.

[0067] The AODD Pump operates on the principle of reciprocating motion generated through the expansion and contraction of diaphragms within the pump, driven by compressed air. This reciprocating action facilitates the efficient and controlled movement of fluid from a feed source into the high-pressure plunger pump. The design of the AODD Pump, with its double diaphragm mechanism, ensures a continuous flow of fluid, minimizing pulsations and providing a steady supply to meet the demands of high-pressure processing. In a preferred embodiment of the present invention of the homogenizer apparatus (**100**), the AODD Pump is configured to work in seamless coordination with the drive unit (**102**), which is responsible for the reciprocating motion of the high strength wear-resistant material like ceramic plungers (**106**) within the cylinders (**104**) of the high-pressure plunger pump. This coordination is crucial for maintaining a synchronized flow rate and pressure of the fluid being processed, enhancing the charging process, and ensuring that a consistent and adequate supply of fluid is available to the cylinders, thereby optimizing the overall efficiency of the fluid processing operation.

[0068] Electrically operated pumps are designed with materials compatible with the fluids they handle. These pumps can handle a wide range of fluids, including those with high viscosity or containing solids, making them ideal for homogenization processes where different materials need to be mixed thoroughly. Electrically operated pumps may be more energy-efficient than pneumatic versions. They offer better control over flow rates and pressures, which can be adjusted by controlling the motor speed. The gentle pumping action of the diaphragms ensures low shear, which is essential in applications like food processing or pharmaceuticals where maintaining the integrity of the fluid's components is necessary. In homogenizer applications, the electrically operated pump's ability to handle varying viscosities and delicate materials without degradation makes it a preferred choice. Its efficient and hygienic operation aligns well with the stringent requirements of industries that rely on clean and precise fluid-handling processes.

[0069] The integration of the AODD or Electrically operated Pump into the homogenizer apparatus represents a significant advancement in fluid processing technology, addressing common limitations associated with fluid supply in high-pressure applications. By leveraging

the unique operational characteristics of the AODD or Electrically operated Pump, including its capability to handle a wide range of fluids and its resilience in demanding operational environments, this embodiment ensures enhanced operational efficiency, reliability, and consistency in fluid processing.

[0070] **Figure 8** illustrates Priming Valve in the Homogenizer Apparatus. In this embodiment of the present invention focusses on a homogenizer apparatus (100) that is equipped with a priming valve (702) arranged in an apparatus to optimize the priming process within high pressure piping and the high-pressure plunger pump, aiming to enhance operational efficiency and reliability. Effective priming of high-pressure fluid processing systems is crucial for avoiding air pockets that can negatively affect processing efficiency and reliability. Air pockets within the system can lead to inconsistent fluid pressure, compromised shear and mixing efficiency, and potential damage to system components. The incorporation of a dedicated priming valve (702) of the present invention addresses these challenges by ensuring thorough priming of the system prior to operation.

[0071] Referring to Figure 8, this embodiment showcases a homogenizer apparatus (100) that integrates a priming valve (702) within high pressure piping, as well as being connected to the high-pressure plunger pump. This priming valve (702) is specifically engineered for the purpose of priming the system — that is, filling the microfluidic interaction chamber (204) and the high-pressure plunger pump with fluid while expelling any trapped air, thereby ensuring that the system is free from air pockets before the commencement of the fluid processing operation. The priming valve (702) operates by allowing fluid to flow into the microfluidic interaction chamber (204) and the high-pressure plunger pump, filling all internal spaces and displacing air through designated air release points. This process is critical for establishing an initial fluid path that is devoid of air, ensuring that when the high-pressure plunger pump begins its operation, the fluid dynamics are not hindered by air resistance or cavitation, which can severely impact processing performance.

[0072] In a preferred embodiment of the present invention, as depicted in Fig. 8, discloses incorporating the priming valve (702) within high pressure piping, and in strategic connection with the high-pressure plunger pump, this embodiment ensures a highly effective and efficient priming process. The location and arrangement of the priming valve (702) in an apparatus facilitate immediate action on the area's most susceptible to air entrapment, thereby enhancing the overall efficiency and reliability of the fluid processing. This facilitates system priming and not only improves the operational consistency of the homogenizer apparatus but also

contributes to the longevity of the system by reducing the potential for damage caused by improper priming. The specific addition of the priming valve (702) tailored for this purpose exemplifies a thoughtful and effective solution to a common challenge in high-pressure fluid processing.

[0073] Figure 9 illustrates Integrated Check Valves in the Homogenizer Apparatus. In this embodiment, the incorporation of check valves focusses on the innovative use of integrated check valves within a homogenizer apparatus to facilitate enhanced fluid dynamic efficiency and flexibility in pressure management. Particularly, for effective pressure management is crucial in high-pressure fluid processing applications, requiring robust mechanisms to maintain operational integrity and efficiency. Traditional check valve systems often present limitations in adaptability and maintenance, hindering optimal performance in varying processing conditions. The introduction of integrated check valves offers a transformative solution to these challenges. Referring to Figure 8 of the accompanying drawings, this embodiment showcases the incorporation of integrated check valves within the homogenizer apparatus (100), specifically designed for high-pressure fluid processing. These valves are integral to creating an alternate flow path configuration, thereby optimizing the fluid dynamic efficiency and offering unmatched flexibility in managing pressures within the system.

[0074] In a preferred embodiment of the present invention, the integrated check valves are strategically vertically arranged in relation to the cylinders (104), where each valve operates under a one-way spring-loaded mechanism. This design includes an elongated stem (304) equipped with a spring-loaded member (308) and O-rings (310, 316) for enhanced sealing, coupled with a cap (312) designed to rest on an inner race of a bearing (314), collectively enhancing the valve's functionality under high-pressure conditions. A distinctive feature of these valves is their modular design, allowing for the independent replacement of any one valve without necessitating the disassembly or replacement of other components within the system. This modularity significantly contributes to the maintenance efficiency and reduces downtime, ensuring the homogenizer apparatus maintains peak performance with minimal operational interruptions. integrated check valves may be a suction check valves, a tee and a discharge check valve, effectively providing an alternate flow path configuration. This innovative arrangement not only enhances the fluid dynamic efficiency but also introduces unparalleled flexibility in pressure management within the high-pressure plunger pump.

[0075] In an exemplary embodiment of the present invention, by integrating the integrated check valves, the homogenizer apparatus achieves a notable advancement in high-pressure

fluid processing technology. This configuration facilitates the development of high pressure for fluid processing by effectively managing the fluid flow through a plurality of strategically arranged external check valves. The alternate flow path configuration provided by the integrated check valves addresses the need for enhanced fluid dynamic efficiency and operational flexibility, marking a significant improvement over traditional check valve system.

[0076] **Figure 10** illustrates an embodiment of zonal separation within the Homogenizer Apparatus. This embodiment focusses specifically on the innovative segregation of operational areas within a homogenizer apparatus to manage contamination risks effectively. Traditional systems often struggle with effectively segregating areas of varying contamination risks, potentially compromising operational safety and product integrity. The innovative approach of zonal separation within the homogenizer apparatus addresses these challenges head-on. Referring to Figure 10 of the accompanying drawings, this embodiment vividly illustrates the strategic implementation of zonal separation within the homogenizer apparatus (100), categorizing operational areas into a "Green Zone" and a "Red Zone." This division is predicated on the contamination risk levels associated with different stages of the fluid processing operation.

[0077] In an embodiment of the present invention, at the heart of the apparatus this zonal separation is the use of bellows and a partition wall, arranged to encapsulate the plurality of external check valves (202). This arrangement not only enhances the structural integrity of the apparatus but also minimizes vibration-induced wear, which is crucial for maintaining the durability and operational efficiency of the system. The bellows within the external check valves are adeptly arranged to accommodate thermal and pressure-induced expansions and contractions, thereby ensuring a leak-proof and durable connection between the external check valves and the high-pressure system. This feature is integral to maintaining the system's integrity and operational reliability under varying conditions. The partition wall serves a critical function in segregating the high-pressure zones from lower-pressure zones within the apparatus. This segregation is instrumental in enhancing operational safety and efficiency by distinctly isolating areas based on their contamination risk levels.

[0078] In an exemplary embodiment, the delineation of the apparatus into a "Red Zone" and a "Green Zone" represents to contamination risk management. The "Red Zone" is designated for operations with a higher contamination risk, requiring stringent controls and isolation to prevent cross-contamination. Conversely, the "Green Zone" encompasses operations with lower contamination risks, allowing for more flexibility in handling and

processing. This zonal separation not only enhances the safety protocols within the homogenizer apparatus but also significantly improves contamination control measures. By effectively managing areas of varying contamination risks, the embodiment ensures a safer, more controlled environment for fluid processing

[0079] The present invention provides a simplified multiplex pumping apparatus for processing of a fluid for high-pressure applications. The multiplex pumping apparatus is capable of processing the fluid at a high production rate. The simple design of the multiplex pumping apparatus also improves ease of maintenance and reparability.

[0080] It would be appreciated by a person skilled in the art that the multiplex pumping apparatus described above may be used for emulsifying, suspending, particle size reduction, dispersing, dissolving, mixing various fluids in the pharmaceutical, beverage, chemical industries and the like.

[0081] In view of the present disclosure, which describes the present invention, all changes, modifications and, variations within the meaning and range of equivalency are considered within the scope of the invention. It is to be understood that the aspects and embodiment of the disclosure described above may be used in any combination with each other. Several of the aspects and embodiment may be combined together to form a further embodiment of the disclosure.

We claim:

1. A homogenizer apparatus (100) for fluid processing, comprising:

a high-pressure plunger pump with a plurality of cylinders (104), each cylinder (104) receiving fluid pumped by a reciprocating motion of one or more high-strength wear-resistant material like ceramic plungers (106), and housed within a mounting block (108) aligned for high-pressure applications;

a low and high-pressure seals (118, 124) within each cylinder (104), along with a ceramic bearing (122) and a U-cup seal to enhance durability and reduce contamination risks;

a drive unit (102), such as a motor, connected to the plungers via driveline and fluid side couplings (130) to enable their reciprocating motion;

a plurality of external check valves (202) vertically arranged in relation to the cylinders (104), each valve being one-way spring-loaded to facilitate the development of high pressure for fluid processing and each of the plurality of external check valves includes a plunger assembly (302), wherein the plunger assembly (302) comprises of an elongated stem (304) with a spring-loaded member (308) and O-rings (310, 316) for tight sealing, and a cap (312) designed to rest on an inner race of a bearing (314), enhancing the valve's functionality under high pressure, wherein the plurality of external check valves (202) are arranged for modularity of part replacement, allowing for the independent replacement of any one valve without necessitating the disassembly or replacement of other valves, thereby improving maintenance efficiency and reducing downtime;

a microfluidic interaction chamber (204) integrated with the high-pressure plunger pump, featuring orifices with fixed geometry made of wear-resistant material for effective mixing and shearing of the fluid under high pressure and the chamber operates in conjunction with the high-pressure pump to reduce fluid processing time and improve process results;

a priming valve (702) arranged within a high pressure piping at an upstream of the interaction chamber (204), specifically added for priming purposes, to ensure the chamber and the high-pressure plunger pump are appropriately filled and free of air pockets, thus enhancing the efficiency and reliability of fluid processing;

a control and data acquisition unit for monitoring and controlling temperature, pressure, and flow rate of the fluid, and for collecting data from sensors located near the cylinders (104), plungers, and check valves (202);

a variable frequency electronic drive coupled with the drive unit (102), facilitating precise control of fluid pressure through the homogenizer (100);

a pneumatic or electrically operated feed pump, for charging the fluid into the high-pressure plunger pump and the diaphragm of the pneumatic or electrically operated feed pump facilitates a reciprocating motion to pump the fluid efficiently and is configured to work in tandem with the drive unit (102) to enhance the charging process and ensure consistent fluid supply to the cylinders (104);

a bellows and a partition wall arranged to encapsulate the plurality of external check valves (202), enhancing structural integrity and minimizing vibration-induced wear wherein the bellows are arranged within external check valves (202) to accommodate the thermal and pressure-induced expansions and contractions, ensuring a leak-proof and durable connection between the external check valves (202) and the high-pressure system and the partition wall segregate the high-pressure zones from lower-pressure zones within the apparatus enhancing the operational safety and efficiency of the homogenizer.

2. The apparatus (100) as claimed in claim 1, wherein each of the high strength wear resistant material like ceramic plungers (106) is configured to withstand high temperature and pressure conditions for enhanced processing efficiency.

3. The apparatus (100) as claimed in claim 1, wherein the low and high-pressure seals (118, 124) in each cylinder (104) are U-cup seals, specifically designed for maintaining high-pressure integrity.

4. The apparatus (100) as claimed in claim 1, wherein the plunger assembly (302) are configured with O-rings (310, 316) made of a material resistant to chemical corrosion and high temperature.

5. The apparatus (100) as claimed in claim 1, wherein the external check valves (202) are an integrated valve which may be a suction check valve, a tee, and a discharge check valve, providing an alternate flow path configuration to enhance the fluid dynamic efficiency and flexibility in pressure management within the high pressure plunger pump.

6. The apparatus (100) as claimed in claim 1, wherein the pneumatic operated feed pump is an air-operated double diaphragm feed (AODD) pump.

7. The apparatus (100) as claimed in claim 1, wherein the electrically operated feed pump is an electrically driven pump.
8. The apparatus (100) as claimed in claim 1, comprising a heat exchanger connected downstream of the microfluidic interaction chamber (204) for regulating the temperature of the processed fluid.
9. The apparatus (100) as claimed in claim 1, wherein the control and data acquisition unit is configured to adjust the variable frequency electronic drive based on real-time data from the temperature and pressure sensors.
10. The apparatus (100) as claimed in claim 1, wherein the microfluidic interaction chamber (204) is configured to handle multiple types of fluids, including biological fluids and chemicals, without risk of cross-contamination.
11. The apparatus (100) as claimed in claim 1, wherein the variable frequency electronic drive includes a Proportional-Integral-Derivative (PID) controller (408) for refined control over the drive unit's speed and torque.
12. The apparatus (100) as claimed in claim 1, wherein the mounting block (108) includes a fork (110) for accurate alignment of the cylinders (104), facilitating high-precision fluid processing.
13. The apparatus (100) as claimed in claim 1, wherein the bellows and partition wall provide a barrier to separate the apparatus into a red zone and a green zone, with the red zone designated for high contamination risk operations and the green zone for operations with lower contamination risk, thereby enhancing safety and contamination control within the homogenizer apparatus.
14. A method for processing fluids using a homogenizer apparatus (100), comprising:
pumping fluid into a high-pressure plunger pump of the homogenizer (100), which includes a plurality of cylinders (104), each cylinder (104) receiving the fluid pumped by a reciprocating motion of one or more high strength wear-resistant materials like ceramic plungers (106) within a mounting block (108) aligned for high-pressure applications;

ensuring durability and contamination prevention by maintaining fluid within low and high-pressure seals (118, 124) in each cylinder (104), supported by a ceramic bearing (122) and a U-cup seal;

driving the high strength wear-resistant material like ceramic plungers (106) in a reciprocating motion using a drive unit (102), such as a motor, connected via driveline and fluid side couplings (130);

developing high pressure for fluid processing by passing the fluid through a plurality of vertically arranged external check valves (202), each external check valves being one-way spring-loaded connected with plunger assembly (302) and the plunger assembly (302) comprising an elongated stem (304) with a spring-loaded member (308) and O-rings (310,316) for tight sealing, and a cap (312) resting on an inner race of a bearing (314) to enhance valve functionality under high pressure and integration of integrated check valves, comprising suction check valves, a tee, and a discharge check valve, to provide an alternate flow path configuration for enhanced fluid dynamic efficiency and pressure management flexibility;

priming the high-pressure system and the microfluidic interaction chamber (204) before processing begins to ensure the chamber and system are properly filled and free of air pockets, utilizing a specifically added priming valve (702) for this purpose, thus enhancing processing efficiency and reliability;

mixing and shearing the fluid in the microfluidic interaction chamber (204) integrated with the high-pressure plunger pump, where the chamber features orifices with fixed geometry made of wear-resistant material. The chamber's operation is aligned to reduce fluid processing time and improve process results;

monitoring and controlling the temperature, pressure, and flow rate of the fluid during processing, utilizing a control and data acquisition unit that collects data from sensors located near the cylinders (104), plungers, and check valves (202);

precisely controlling the fluid pressure throughout the homogenizer process using a variable frequency electronic drive coupled with the drive unit (102);

charging the fluid into the high-pressure plunger pump using a pneumatic or electrically operated feed pump, specifically an air-operated double diaphragm feed pump or an electrically driven feed pump, wherein the double diaphragm of the feed pump facilitates a reciprocating motion to pump the fluid efficiently and is configured to work in tandem with the drive unit (102) to enhance the charging process and ensure consistent fluid supply to the cylinders (104);

implementing bellows and a partition wall in conjunction with the external check valves to provide mechanical flexibility and isolation, respectively, wherein the partition wall and

bellows arrangement effectively separates operational zones within the homogenizer apparatus, enhancing structural integrity and operational isolation between different processing stages.

15. The method as claimed in claim 14, including the step of adjusting the reciprocating motion of the high strength wear resistant material like ceramic plungers (106) based on the fluid type and processing requirements.

16. The method as claimed in claim 14, wherein controlling the temperature, pressure, and flow rate includes using a PID controller (408) to adjust the variable frequency electronic drive in response to sensor data.

17. The method as claimed in claim 14, comprising the step of cooling the processed fluid using a heat exchanger immediately after it exits the microfluidic interaction chamber (204).

18. The method as claimed in claim 14, wherein the processing of the fluid is adapted based on the fluid type, including adjustments for biological fluids and chemical mixtures.

19. The method as claimed in claim 14, including performing SIP operations using saturated steam or CIP operations using detergents and chemicals to ensure the sanitization and sterility of the homogenizer (100).

20. The method as claimed in claim 14, including the step of calibrating the control and data acquisition unit to optimize processing parameters for different fluid types.

21. The method as claimed in claim 14, wherein the processing includes adjusting the operation of the external check valves (202) to manage the pressure build-up during high-pressure fluid processing.

22. The method as claimed in claim 14, involving the step of utilizing the fork (110) in the mounting block (108) for precise alignment and calibration of the cylinders (104) in the high-pressure plunger pump.

23. The method as claimed in claim 14, wherein the fluid processing is tailored for specific applications such as emulsification, suspension, particle size reduction, dispersing, or dissolving of various fluids.

24. The method as claimed in claim 14, including creating a barrier with bellows and partition wall to separate the homogenizer apparatus into a red zone and a green zone, where the red zone is designated for high contamination risk operations and the green zone for operations with lower contamination risk, thereby enhancing safety and contamination control during the fluid processing.

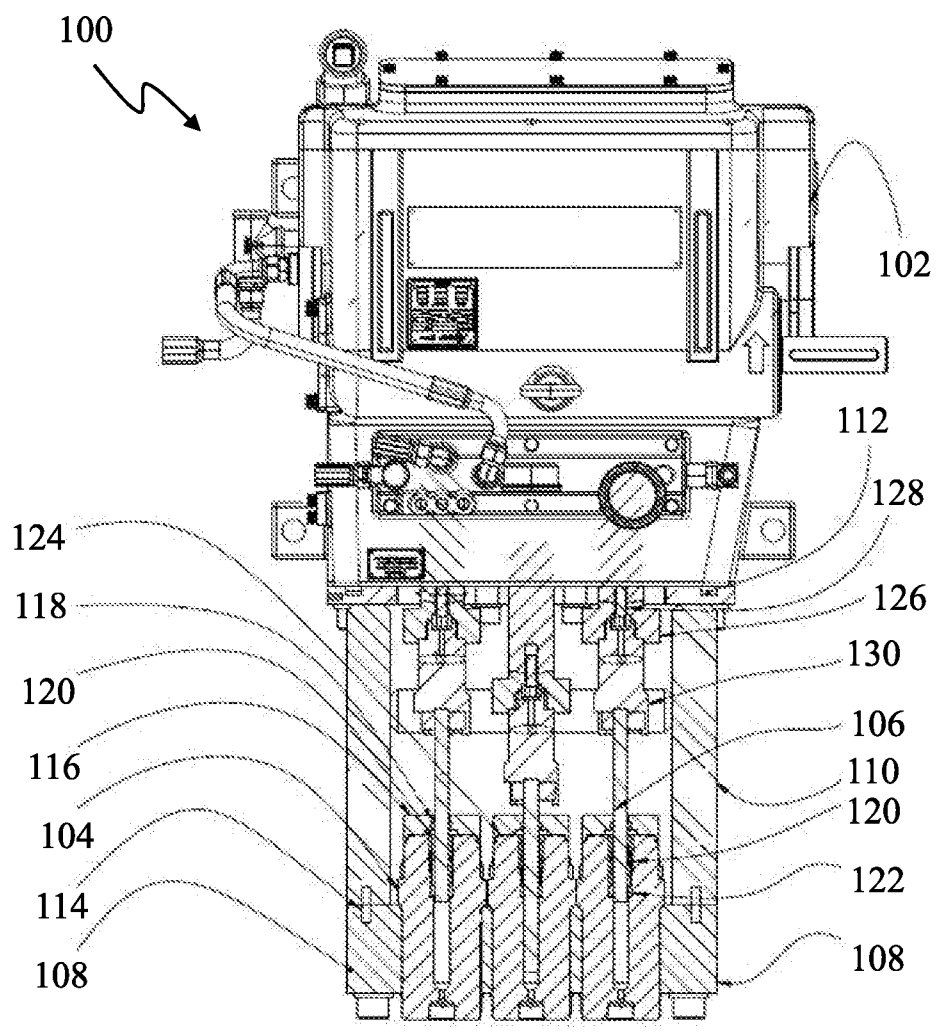


Fig. 1A

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Fig. 1B

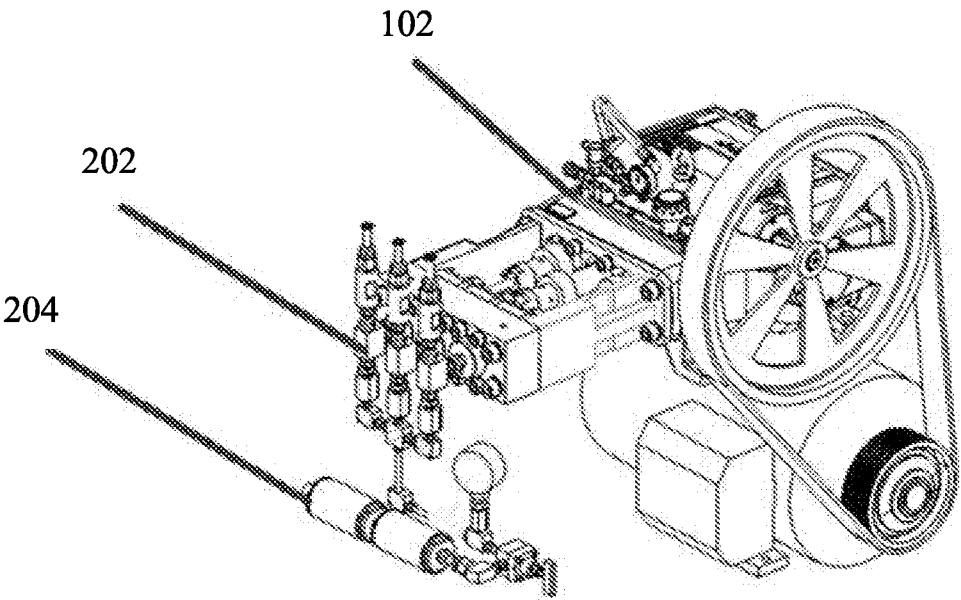


Fig. 2A

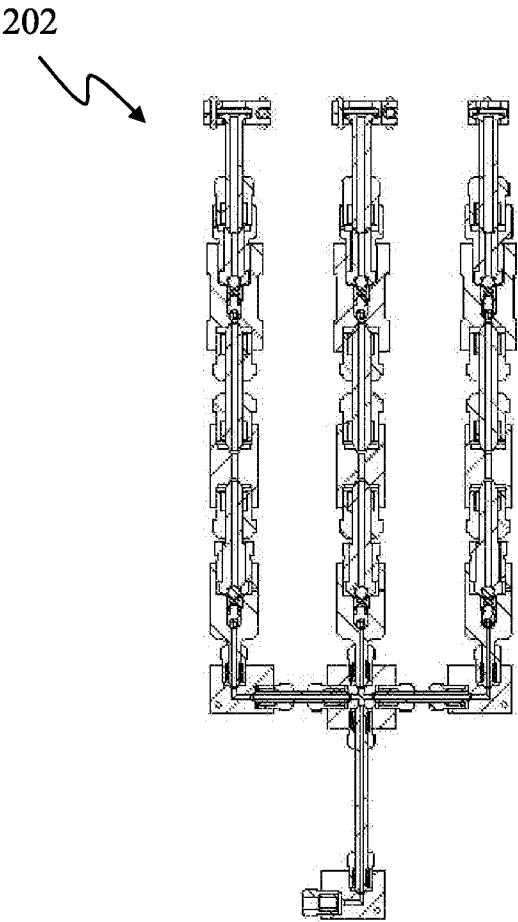


Fig. 2B

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202

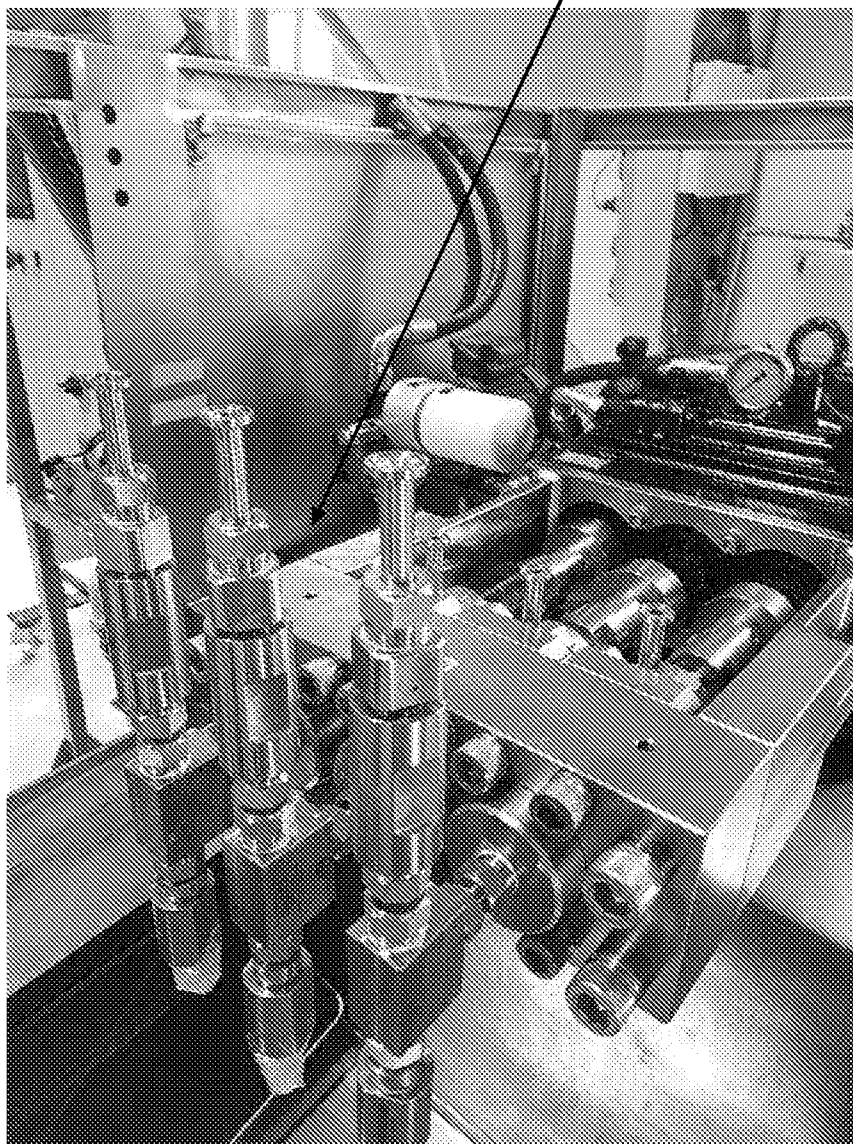


Fig. 2C

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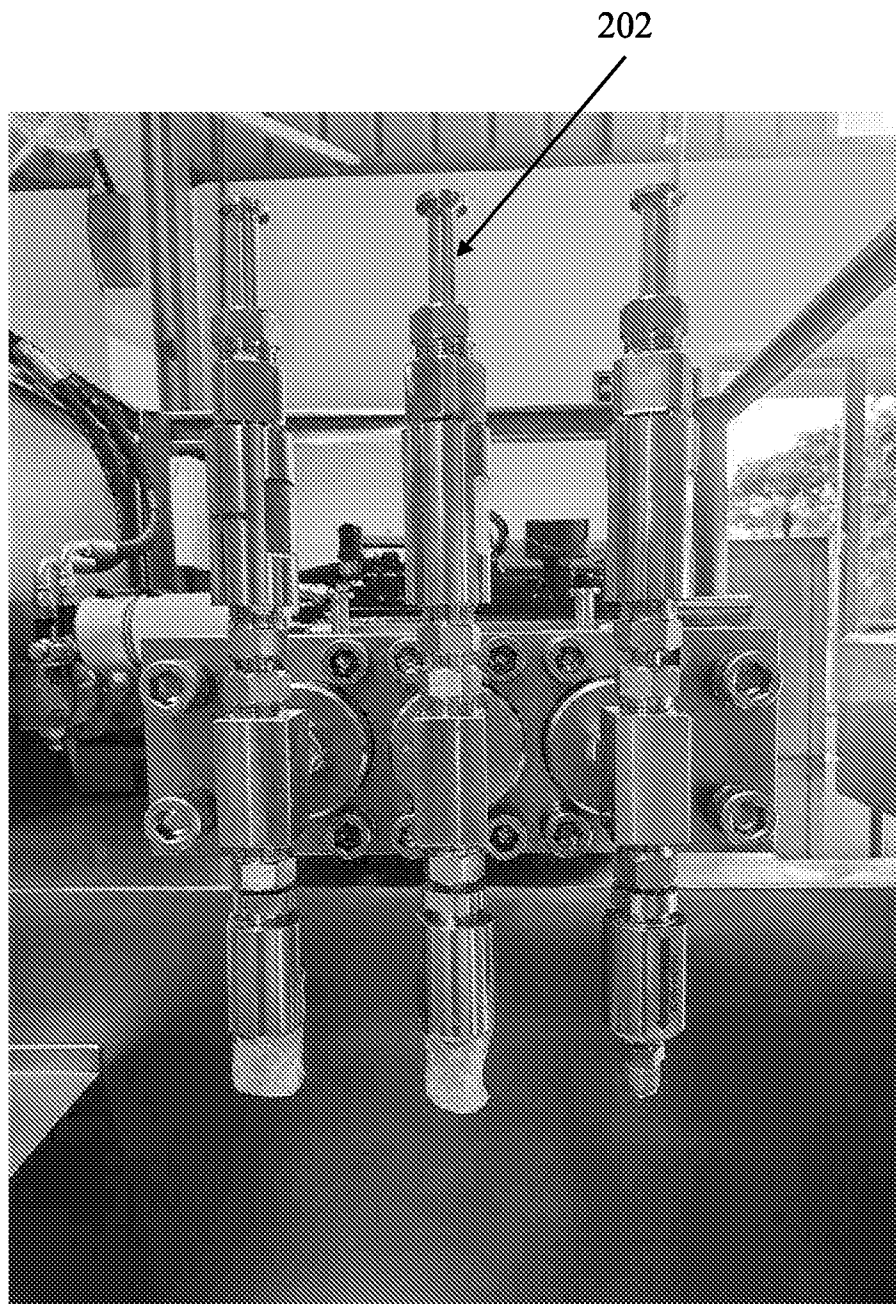


Fig. 2D

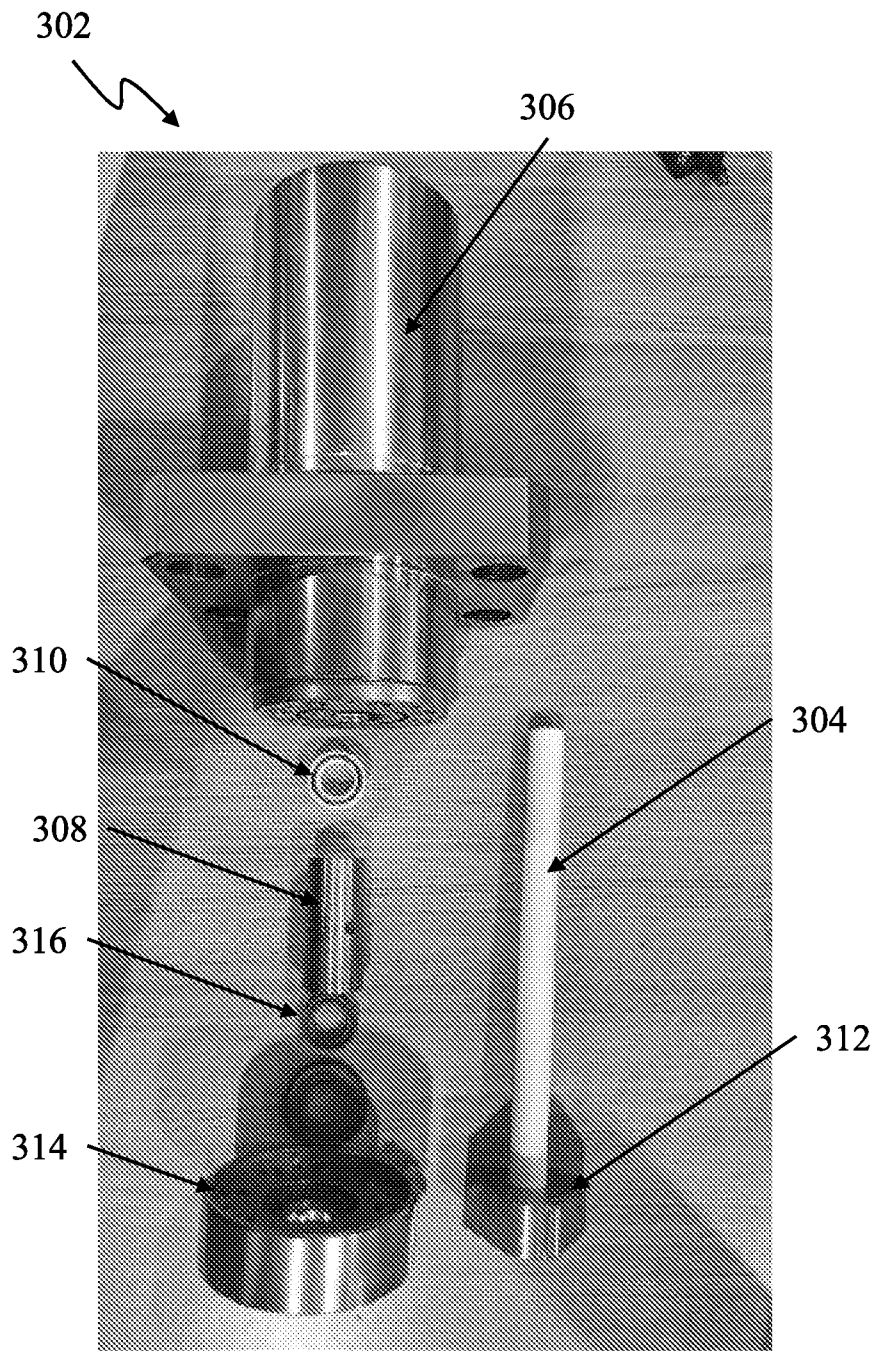


Fig. 3

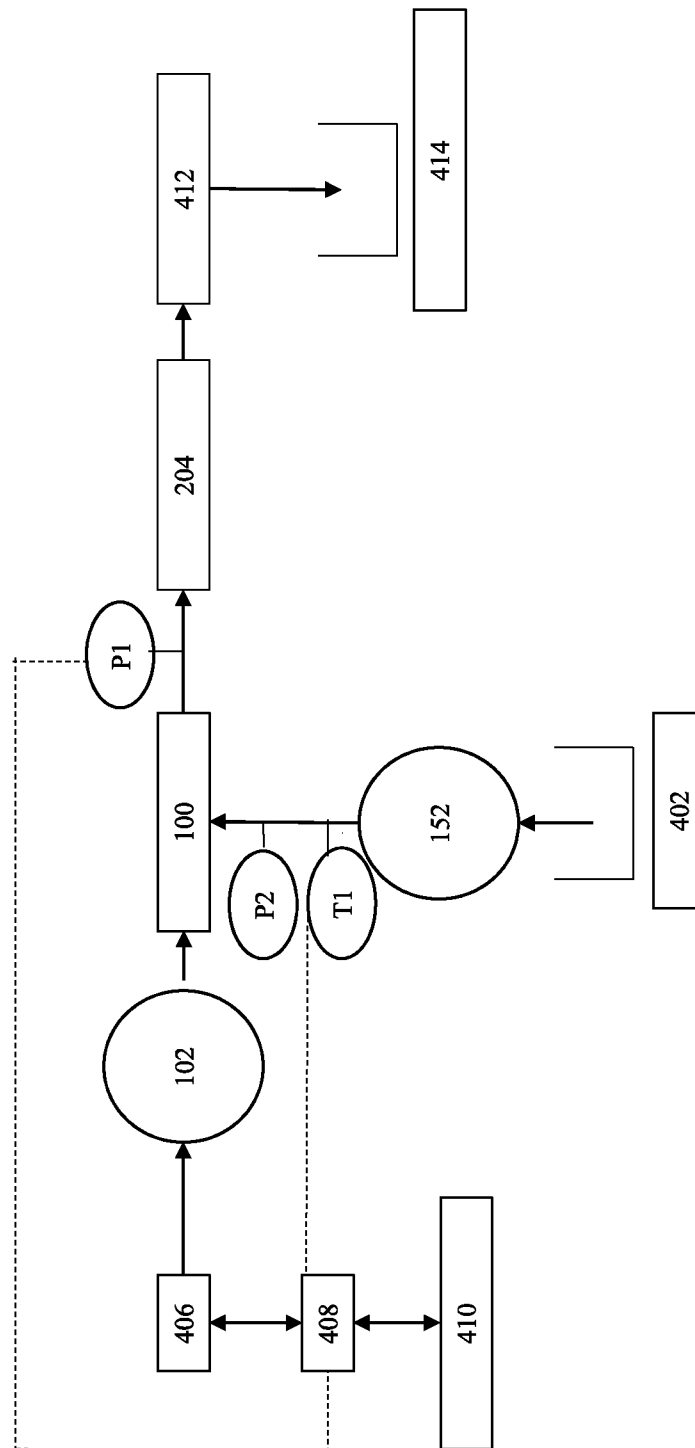


Fig. 4

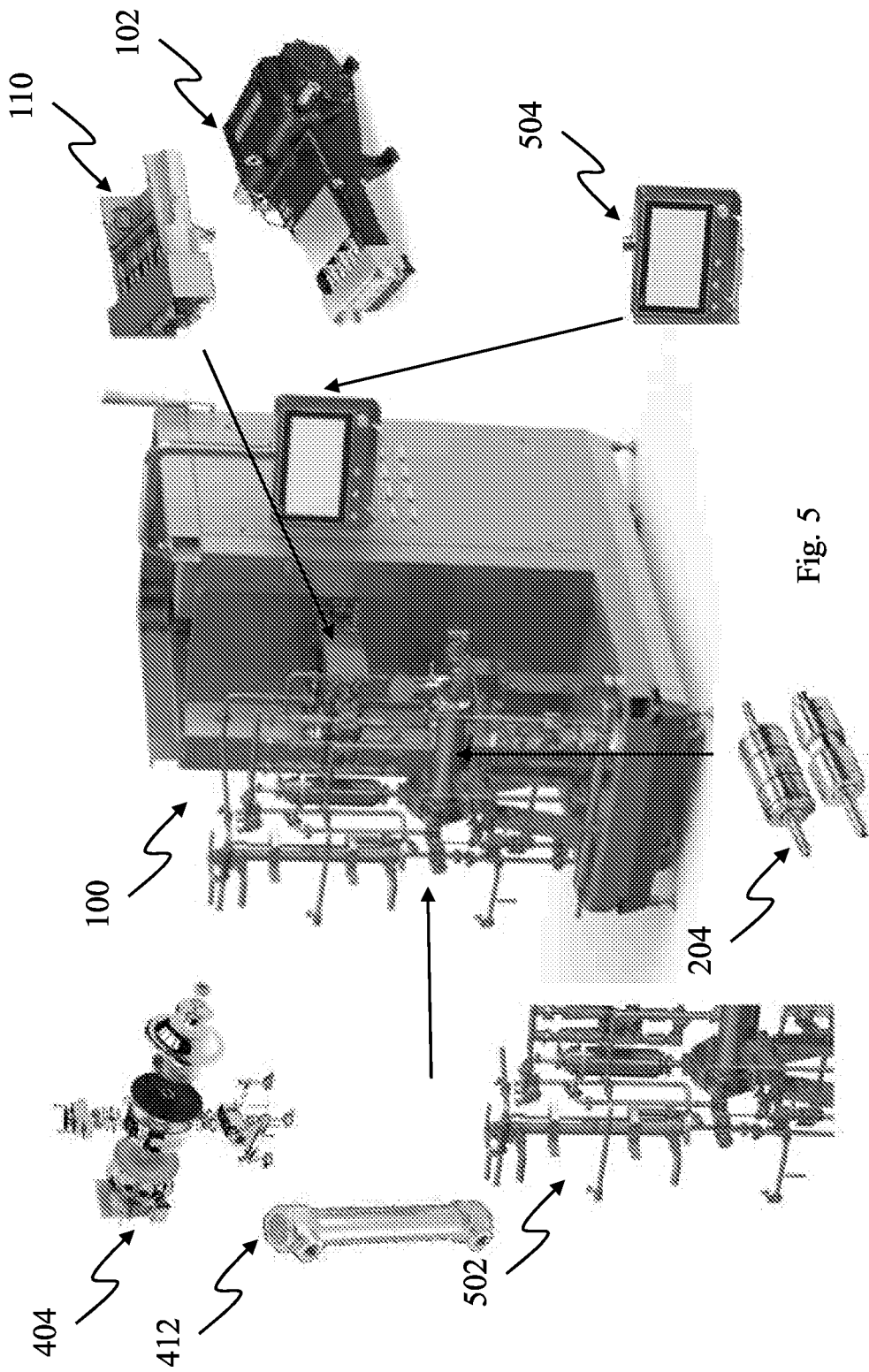


Fig. 5

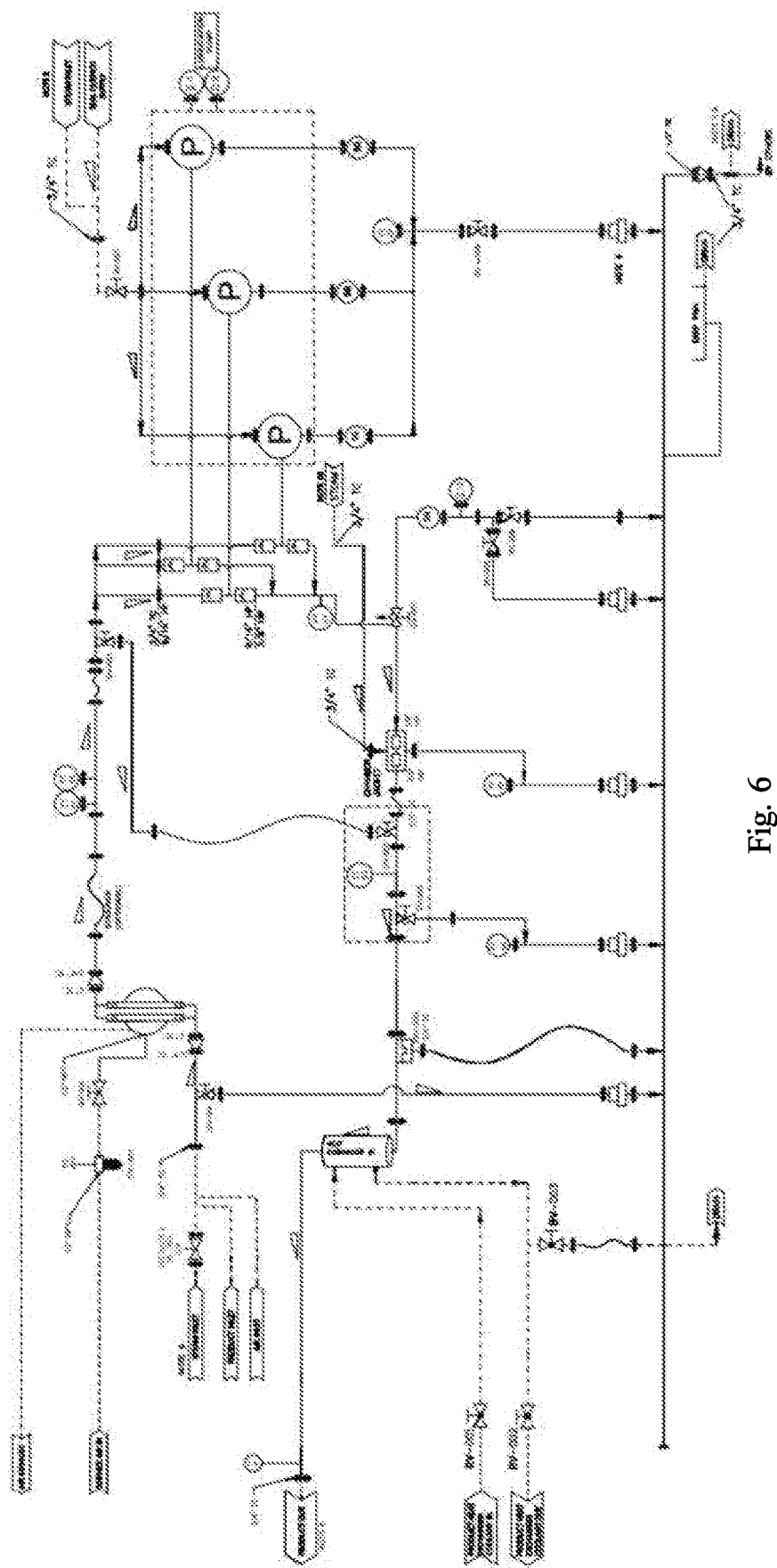


Fig. 6

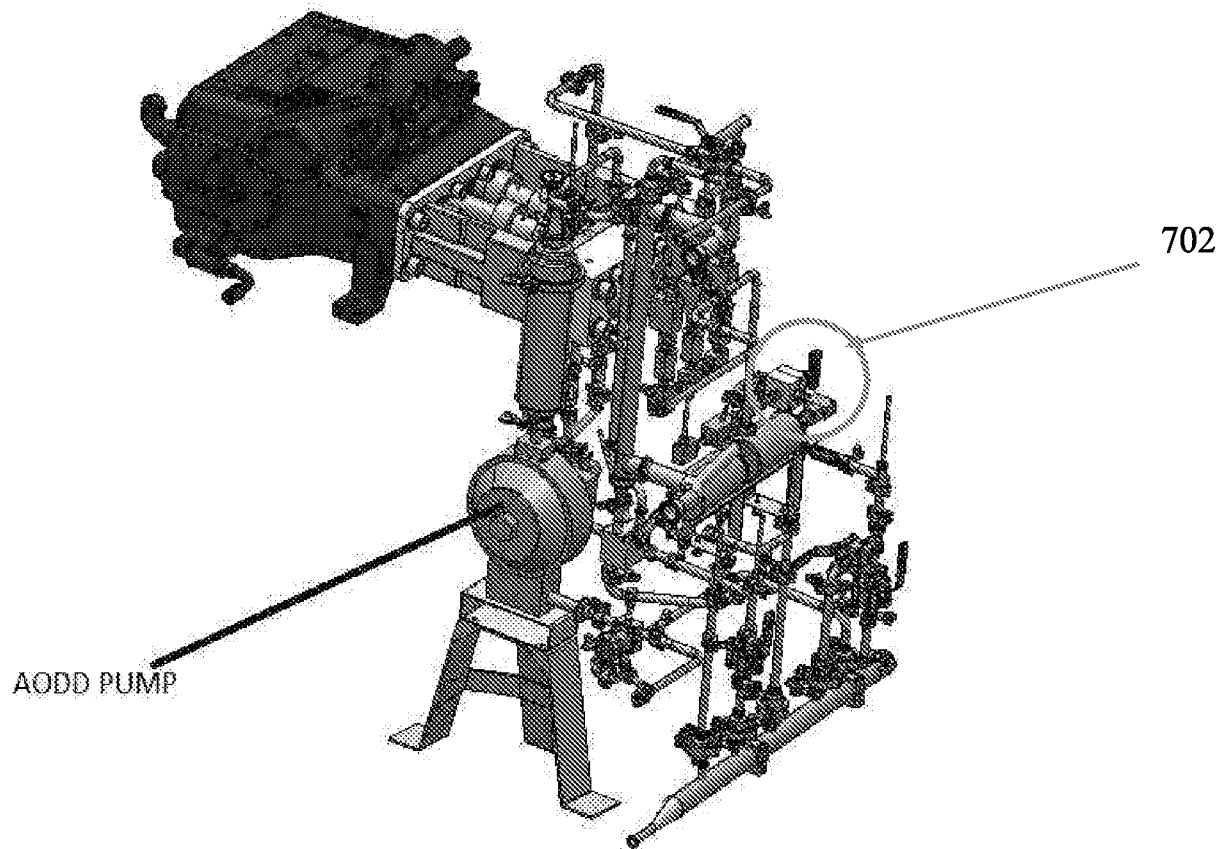
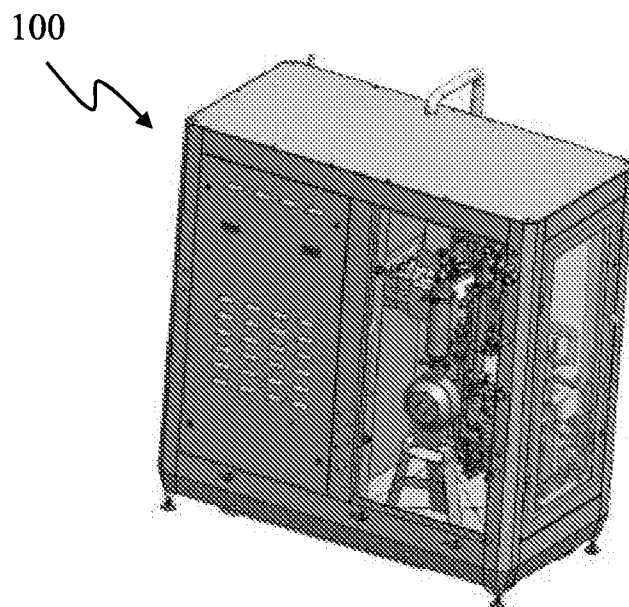


Fig. 7



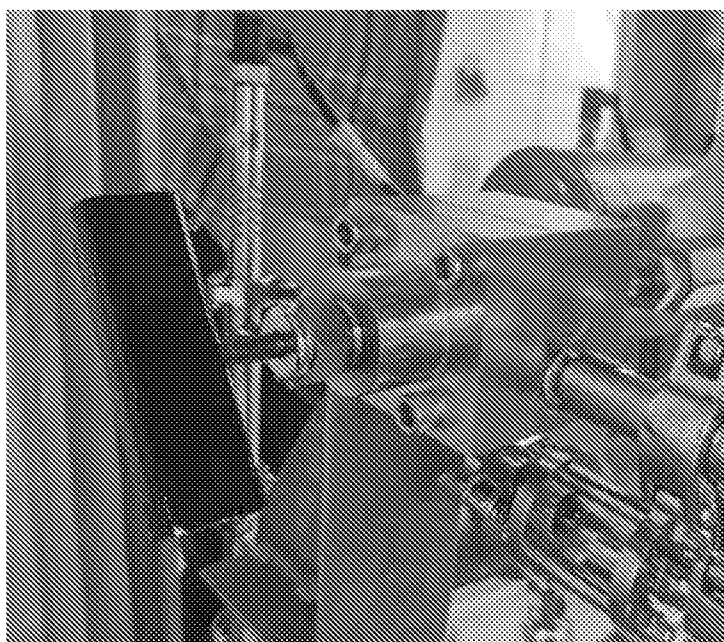
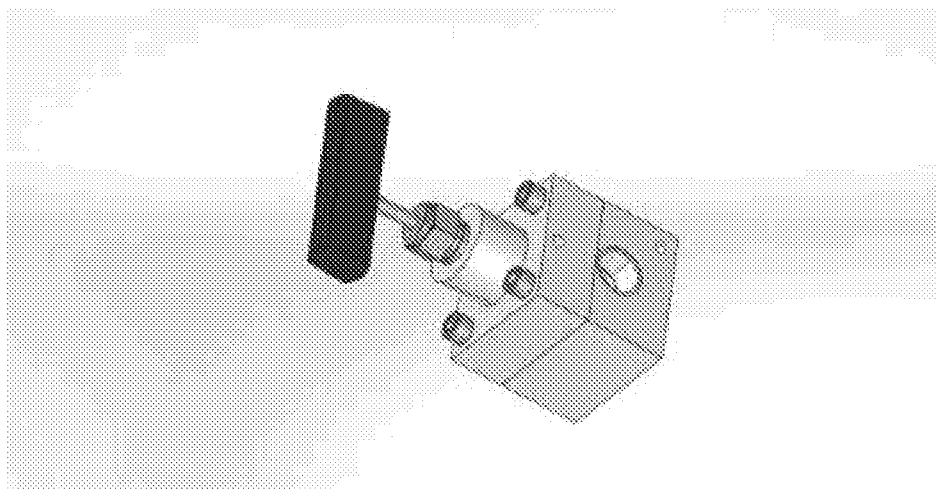


Fig. 8

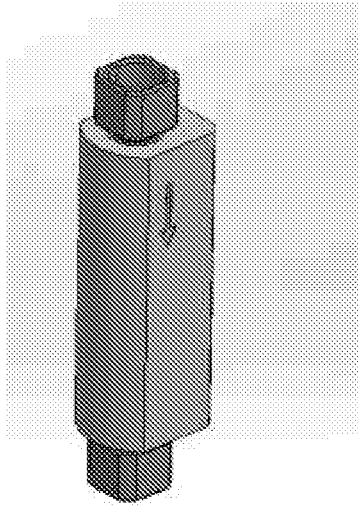
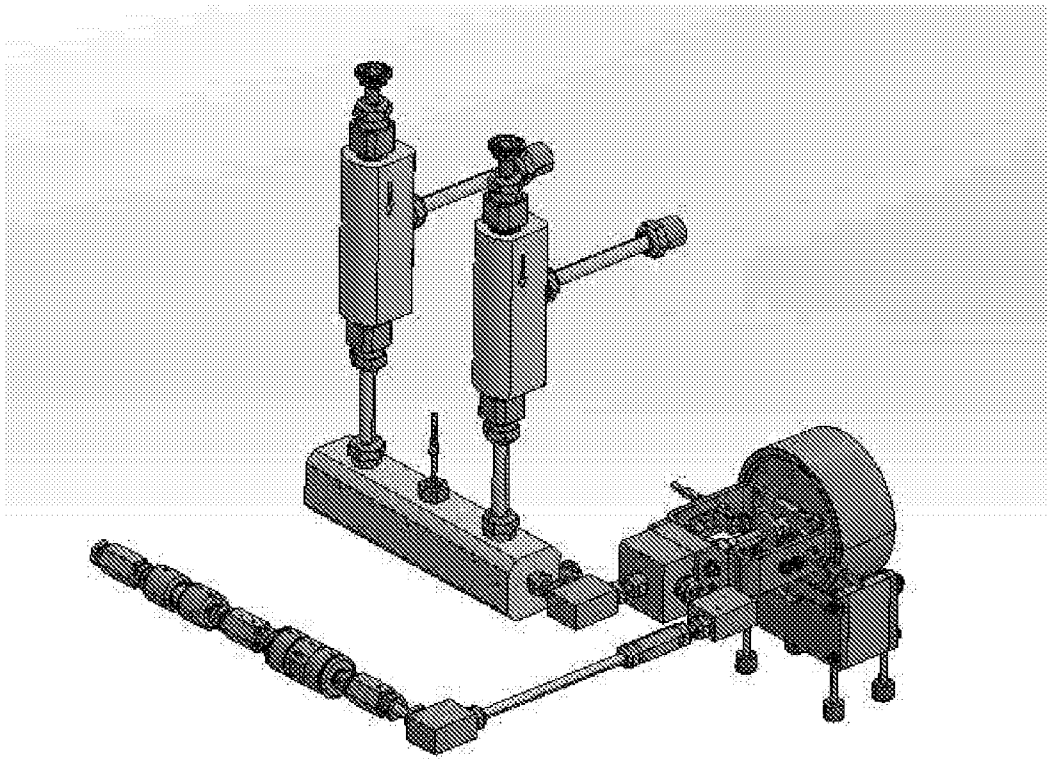


Fig. 9

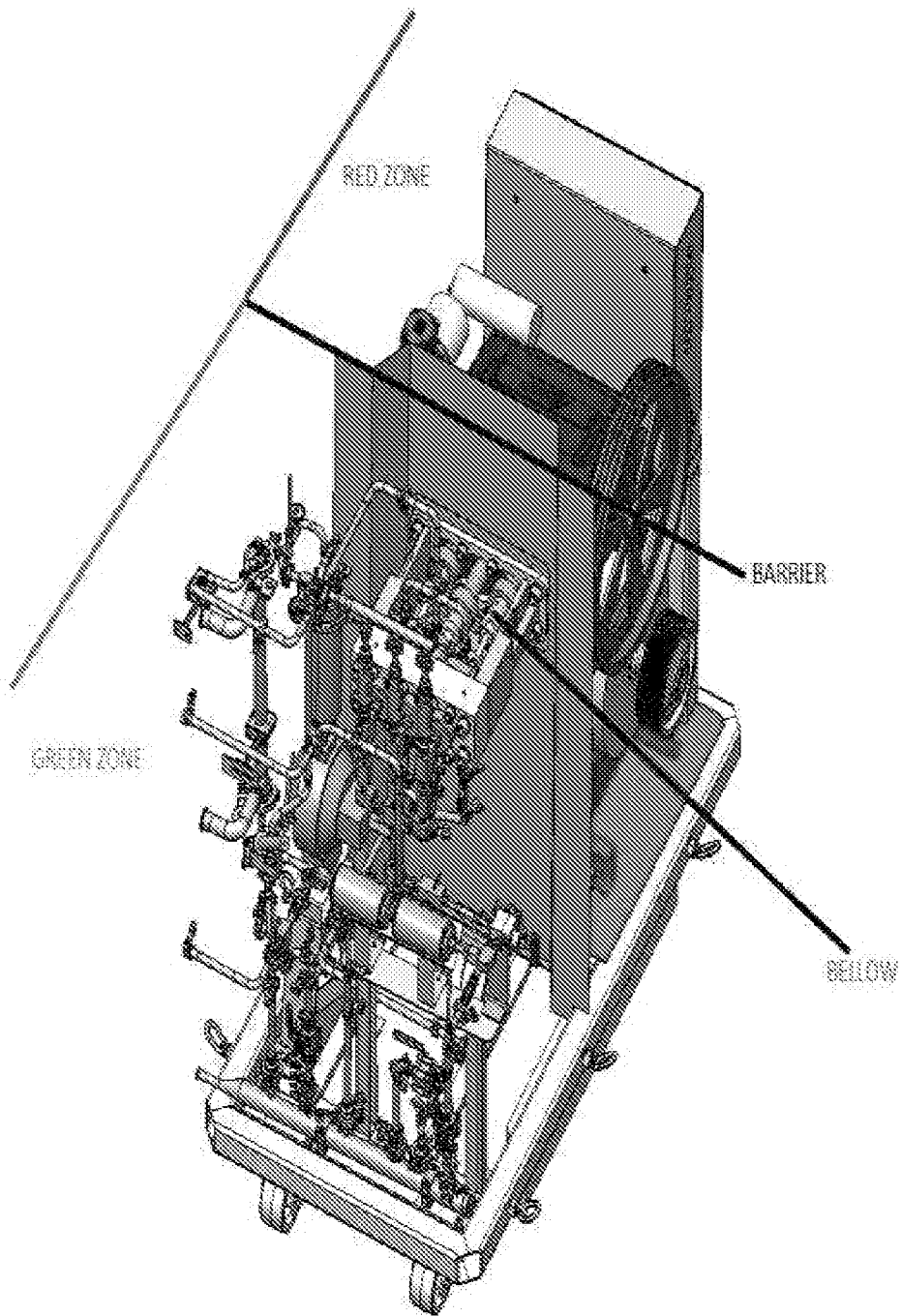


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IN2024/050709

A. CLASSIFICATION OF SUBJECT MATTER
B01F25/60, B01F33/71 Version=2024.01

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)

B01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

PatSeer, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7661873 B2 (GEA NIRO SOVAI SPA) 16 February 2010 (2010-02-16) Column 2 line 44 - column 4 line 52	1-24
A	EP 4182560 A1 (NETZSCH FEINMAHLTECHNIK) 24 May 2023 (2023-05-24) Paragraph 78-95 of English translation of ESPACENET	1-24

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"E" earlier application or patent but published on or after the international filing date

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"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

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"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

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Date of the actual completion of the international search

30-09-2024

Date of mailing of the international search report

30-09-2024

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Facsimile No.

Authorized officer

Ashwani Singh

Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IN2024/050709

Citation	Pub.Date	Family	Pub.Date
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