US 20080038123A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2008/0038123 A1

HILGERS et al.

(43) Pub. Date: Feb. 14, 2008

(54) **PROCESSING AND/OR OPERATING MACHINE COMPRISING AN IONIC LIQUID AS THE OPERATING LIQUID**

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(21) Appl. No.: **11/839,228**

(22) Filed: **Aug. 15, 2007**

Related U.S. Application Data

(63) Continuation-in-part of application No. PCT/EP06/50941, filed on Feb. 15, 2006.

(30) **Foreign Application Priority Data**

Feb. 16, 2005 (DE) 10 2005 007100.7

Publication Classification

(51) **Int. Cl.**

F04B 37/18	(2006.01)
C10M 105/70	(2006.01)
C10M 105/72	(2006.01)
F04B 9/08	(2006.01)
F04B 39/02	(2006.01)
C10M 105/74	(2006.01)

(52) **U.S. Cl.** **417/366**; 415/1; 418/1; 508/256; 508/262; 508/269; 508/388; 508/423

(57) **ABSTRACT**

The invention relates to a processing or working machine comprising a liquid as the operating liquid wherein the invention is characterized in that an ionic liquid constitutes said operating liquid. The invention also relates to the use of operating fluids in processing or working machines, wherein an ionic liquid constitutes the operating liquid and is used, in particular, as a lubricating fluid, barrier fluid, sealing fluid, or a pressure transmission fluid.

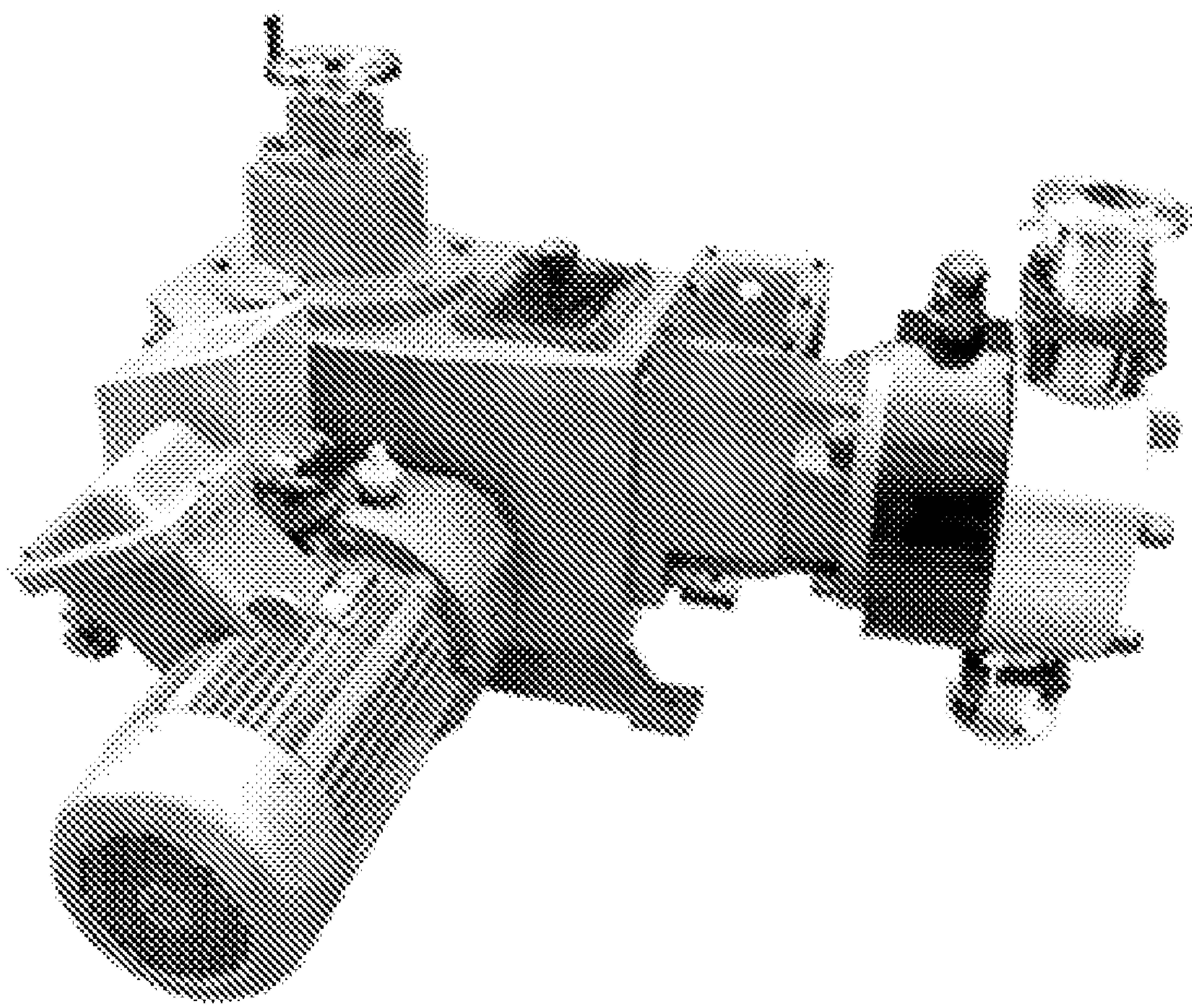


FIG. 1

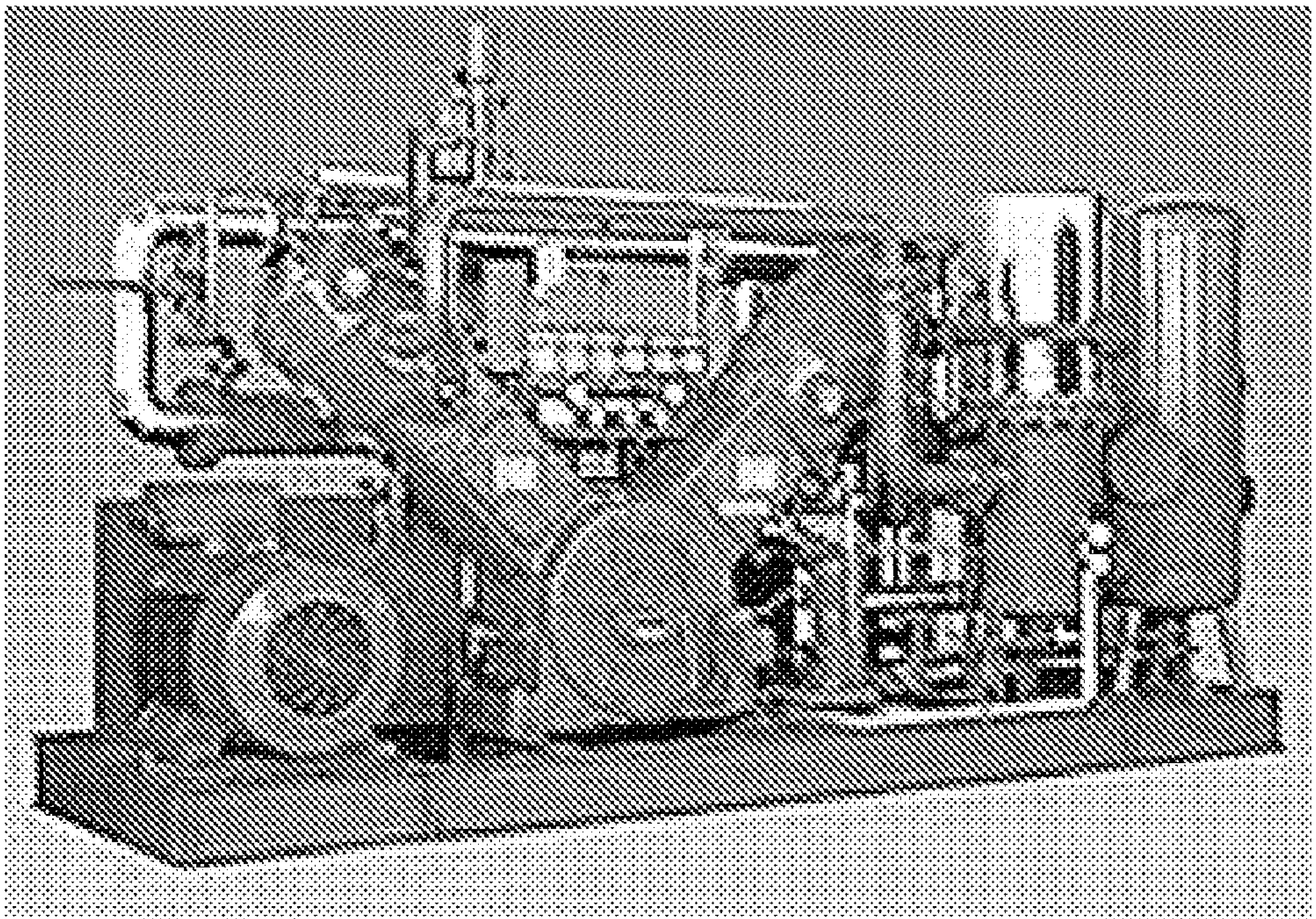


FIG. 2

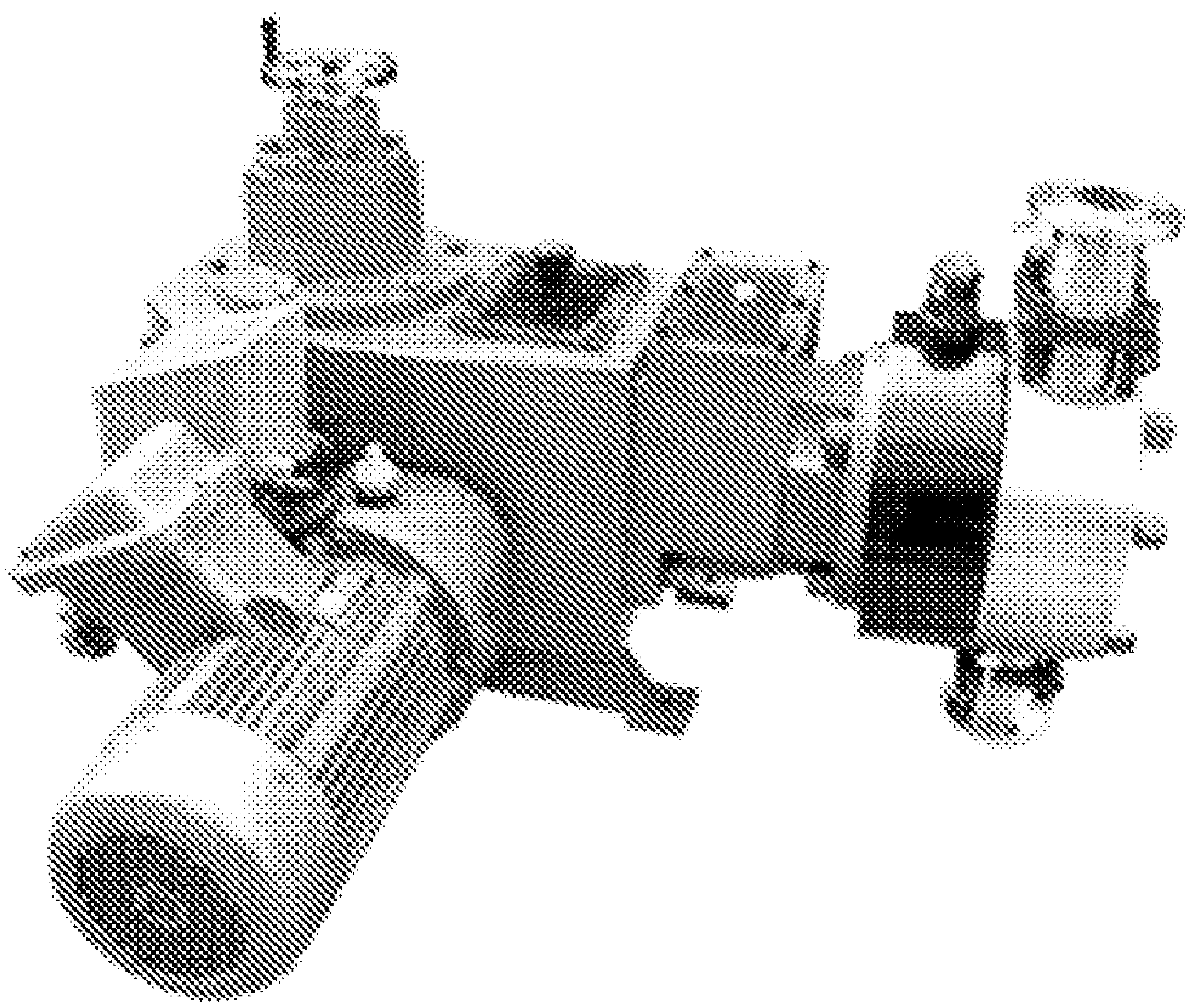


FIG. 3

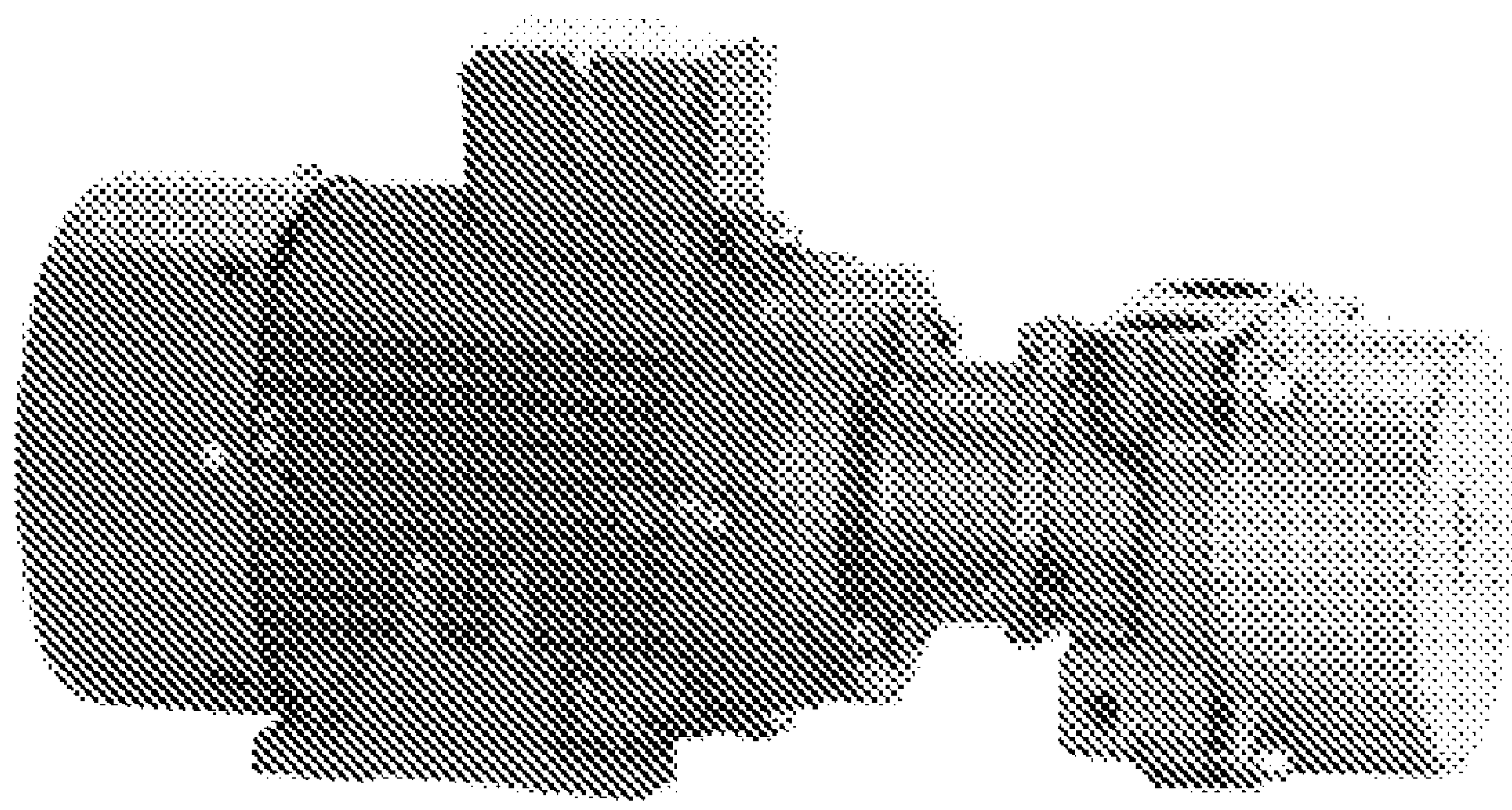
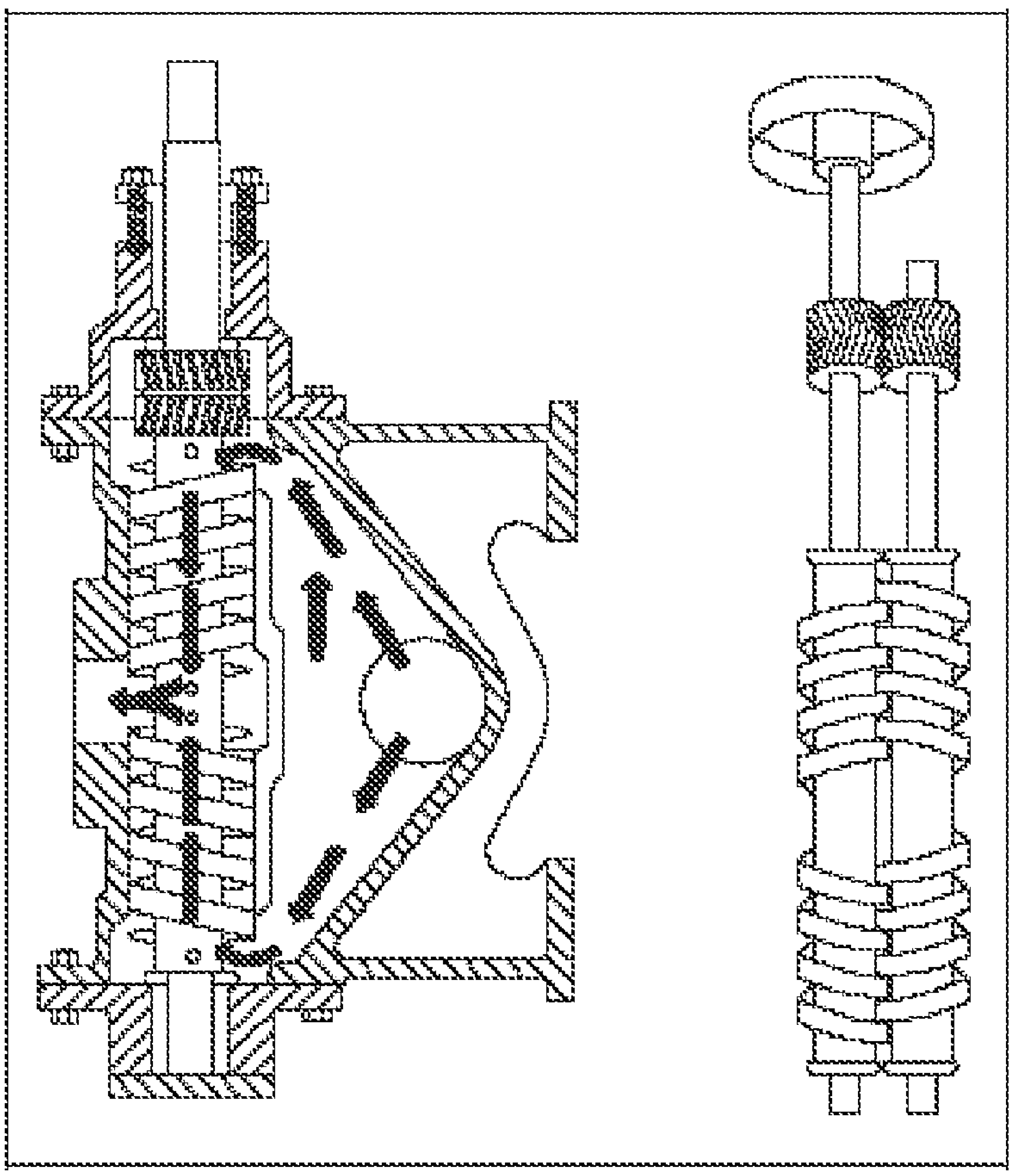


FIG. 4



PROCESSING AND/OR OPERATING MACHINE COMPRISING AN IONIC LIQUID AS THE OPERATING LIQUID

CROSS REFERENCE TO EARLIER FILED APPLICATIONS

[0001] The present application is a CONTINUATION-IN-PART of PCT International Application Serial No. PCT/EP2006/050941 filed Feb. 15, 2006 and published as PCT International Publication No. WO 2006/087333 on Aug. 24, 2006, which claims the benefit of priority of German Patent Application Serial No. DE 10 2005 007100.7 filed Feb. 16, 2005, the entire disclosures of which are hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The invention relates to a processing and/or operating machine comprising an ionic liquid as the operating liquid.

BACKGROUND OF THE INVENTION

[0003] In the case of many conveying, power and operating principles of processing and operating machines, operating liquids are employed to maintain functioning and/or safety.

[0004] Thus, fluids, preferably oils are used as lubricating fluid, sealing fluid, barrier fluid, pressure transfer fluid, i.e. quite generally as operating liquid, in the field of processing machines such as pumps, in particular vacuum pumps, rotary vane pumps, vane-cell pumps, piston pumps, diaphragm pumps etc., in compressors such as screw compressors etc. and in piston machines. This makes it possible for the processing machines to be used at all since it permits a reduction of the wear and tear, friction and of the gap leakage current, for example.

[0005] Typical examples of such applications are:

[0006] a. hydraulic diaphragm pumps. In this case, oil or another fluid is used as hydraulic fluid for the diaphragm actuator and as coupling fluid between diaphragms;

[0007] b. various types of vacuum pumps and compressors such as rotary vane pumps, roots pumps, rotary piston compressors, screw compressors, piston compressors, scroll compressors etc. In this case, lubricant fluids are used for lubrication but also for sealing the compressor systems and for cooling the compressor systems and the conveying fluids;

[0008] c. liquid ring vacuum pumps. These use fluids as operating liquids to produce the conveying effect (fluid piston), for lubrication and for absorbing the heat of compression;

[0009] d. operating machines and operating units such as engines, gears, hydraulic systems etc. In this case, fluids are used as lubricating fluids, i.e. for the lubrication of bearings, for the lubrication of teeth etc. and for power transmission, in particular in the case of a hydraulic units, hydraulic cylinders, lifting devices etc.

[0010] As a result, certain advantages are obtained which consist of the following, among others: a) an increase in effectiveness; b) protection from wear and tear; and c) evaporation cooling, i.e. the fluid evaporates in the pump chambers if the evaporation temperature is exceeded, thus cooling the process gas since the fluid absorbs part of the heat of compression.

[0011] However, there are serious disadvantages involved in such a use of the known fluid means of operation in processing and operating machines. Thus, the vapour pressure of such fluids determines the minimum pressure in a processing machine, with, in the case of an evaporation of the fluid, this having to be eliminated from the process gas in a complex manner.

[0012] Hydraulic diaphragm pumps are a typical example of the disadvantages described. As a result of their hermetic properties with a simultaneously high compressive rigidity and conveying accuracy, such hydraulic diaphragm pumps are preferably employed for critical conveying tasks such as conveying of toxic, environmentally relevant or hygiene fluids, for conveying at high pressures and for the precise dosage of any desired fluids.

[0013] However, in this case, the hydraulic fluid, which is used as a pressure transfer fluid from the piston to the diaphragm, represents a frequently limiting factor. Conventionally, mineral oil or synthetic oil, e.g. polyglycol with a multiplicity of additives or special oil is used for this purpose. As a result of the physiological concerns which this lubricant presents, glycerine is also used in food technology or biotechnology.

[0014] However, all these fluids have disadvantages. Thus, it is found in the case of the use of mineral oil, for example, that dissolved gas restricts the minimum intake pressure of the diaphragm pump to 0.4 bar absolute. The thermal limit is reached at approximately 150° C. Moreover, a strong modification of the viscosity is obtained as a result of a temperature change. The use of synthetic oil has the same disadvantages as mineral oil, with the thermal limit being slightly higher.

[0015] Finally, the use of glycerine requires the application of inhibitors of biological decomposition. Nevertheless, decomposition cannot be prevented. The thermal limit in this case is merely 95° C. The viscosity is adjusted by mixing with water in a complex manner.

[0016] A further typical example of the disadvantages described is presented by liquid ring vacuum pumps. In this case, the rotating fluid ring is required to seal the impeller chambers vis-à-vis each other and for transferring the necessary compression energy onto the gas. The vapour pressure of the ring liquid limits the minimum achievable intake pressure level. At this intake pressure, the impeller chambers fill completely with the evaporating operating liquid and the suction capacity of the liquid ring vacuum pump drops to zero.

[0017] In most cases of application, water is used as the ring liquid. An advantage in this respect is the high specific heat capacity, the continual availability, the environmental compatibility and finally the price. However, the risk of corrosion in the case ferritic materials and the restriction of the area of use to the coarse vacuum of up to approximately 50 mbar have a disadvantageous effect.

[0018] Operating liquids used in practice are preferably water with a vapour pressure at ambient temperature of approximately 23 mbar and oils with a vapour pressure of approximately 1 mbar thus permitting merely operation in the so-called coarse vacuum range. For processes which, in comparison, require these so-called fine vacuum range, other compressors need to be consequently necessarily used for this purpose. However, as a result of their operating principles, these have disadvantages compared with the use of a liquid ring vacuum pump. Particularly in the field of the chemical industry, their use for compressing hydrocarbons is possible only by taking great safety precautions since the compressors that can be used require an explosion-protected design.

[0019] In order to reduce the vacuum range, investigations have therefore already been carried out with oil and different water-based fluids. Reducing the intake pressure level has so far been possible only to a limit of 1 mbar. This slight extension of the field of application, however, is simultaneously accompanied by difficulties in handling the usually toxic or environmentally hazardous operating liquids. At the same time, it had to be ensured that the ring liquid does not react with the usually aggressive and/or corrosive gas to be sucked off. In the case of special applications, oils are also used which have a lower vapour pressure. Such oils, however, lead to contamination of the medium conveyed and present an environmentally risk. The use of chemicals as operating liquids, concentrated sulphuric acid for chlorine gas compression, for example, is also known. However, these applications require increased safety measures as well as additional equipment such as oil separators etc. In all the cases known so far, however, the field of application of liquid ring vacuum pumps remains restricted to the coarse vacuum.

[0020] Finally, piston machines are a further typical example of the occurrence of the disadvantages described. In the case of such piston machines, a possible technical solution for specific applications would be to operate them for the purpose of gas or fluid conveying, with a fluid piston or a fluid master piston, namely with a given satisfactory density difference and non-miscibility. However, this has so far failed as a result of the limits of the known operating liquids, and in particular because the known disadvantages such as evaporation, corrosion, toxicity, gas solubility etc arise in the case of the application of aqueous fluids. The same applies to the use of organic fluids since, in this case, the disadvantages of evaporation, toxicity, volatility etc. arise. Finally, the disadvantages of toxicity, high costs, high density, difficult sealing etc. arise in the case of the use of fluid metals.

[0021] The subsequently published DE 10 2204 024 967 A1 discloses the use of ionic liquids as operating liquid (i.e. the fluid to be conveyed) for thermal absorption pumps, absorption refrigerating machines and thermal transformers. Gas conveying machines, hydraulic diaphragm pumps, liquid ring vacuum pumps and piston machines using ionic liquids as operating liquids are not disclosed in DE 10 2004 024 967 A1.

[0022] DE 103 16 418 A1 discloses the use of ionic liquids as heat carriers for the indirect supply or discharge of heat from a reactor. The document teaches that, as a result of the higher heat absorption of the cooling media, savings in the propulsion power of the pumps are possible and that no specific pump arrangements for conveying the ionic liquids are necessary.

SUMMARY OF THE INVENTION

[0023] The present invention is therefore based on the object of designing a processing and/or operating machine of the type appropriate for its kind which exhibits a fluid as operating liquid such that the disadvantages illustrated are avoided without loosing the advantages of the operating liquids previously employed.

[0024] In its most general embodiment, this invention relates to a device, in particular a pump, comprising an ionic liquid as operating liquid medium, in particular as separating fluid and/or hydraulic fluid.

[0025] A first embodiment of the present invention consists of a gas conveying machine which is characterized in that it comprises an ionic liquid as lubricating and/or barrier fluid.

[0026] A second embodiment of the present invention consists of a hydraulic diaphragm pump which is characterized in that it comprises an ionic liquid as hydraulic fluid.

[0027] A third embodiment of the present invention consists of a liquid ring vacuum pump which is characterized in that it comprises an ionic liquid as ring liquid. This extends the operating range of the pump into the fine vacuum range.

[0028] A fourth embodiment of the present invention consists of a piston-containing machine which is characterized in that it is designed with a piston oscillating in a cylinder in the form of a fluid piston or a fluid master piston positioned in front which consists of an ionic liquid. As a result of the oscillating movement of the fluid piston, a gas, a non-miscible fluid of low density or a fluid of high density can be conveyed.

[0029] The invention moreover, relates to a process for operating the above-mentioned device by using ionic liquids as operating liquid medium. Accordingly, the invention provides a method of operating a machine comprising: including an ionic liquid as an operating fluid in the machine; and operating the machine. The invention also provides a method of equipping a machine comprising: including an ionic liquid in the machine as an operating fluid in the machine. By "operating fluid" is meant a liquid employed by a machine to facilitate operation of a machine. The operating fluid can serve as a lubricant, barrier fluid, hydraulic fluid, ring liquid, fluid piston or any other such fluid. It should be understood that the scope of the invention is use of an ionic liquid as an operating fluid in a machine, wherein the ionic liquid is used other than solely as a heat transfer medium.

[0030] These and other aspects of this invention will be apparent upon reference to the following detailed description, examples, claims and attached figure.

BRIEF DESCRIPTION OF THE FIGURES

[0031] The following drawings are given by way of illustration only, and thus is not intended to limit the scope of the present invention. Advantageous embodiments thereof are described in the claims.

[0032] FIG. **1** depicts an exemplary gas conveying machine of the invention comprising an ionic liquid.

[0033] FIG. **2** depicts an exemplary hydraulic diaphragm pump of the invention comprising an ionic liquid.

[0034] FIG. 3 depicts an exemplary liquid ring vacuum pump of the invention comprising an ionic liquid.

[0035] FIG. 4 depicts an exemplary screw pump of the invention comprising an ionic liquid.

DETAILED DESCRIPTION OF THE INVENTION

[0036] The invention is based on the essential idea of designing a processing and/or operating machine in such a way that the operating medium provided therein, i.e. the operating liquid is an ionic liquid. As a result, surprising advantages are obtained, which are described in detail in the following.

[0037] Ionic liquids consist of ions, i.e. anions or cations and are consequently salts. In contrast to common salts, such as sodium chloride, however, they have a lower melting point and may be fluid even at room temperature. Thus, all salts which exist in the pure form as a fluid at below 100° are considered, by definition, to be ionic liquids.

[0038] Ionic liquids may be referred to as liquid salts. They possess an extremely low vapour pressure (10^{-13} bar), have only a low gas solubility, are not combustible, are frequently physiologically safe and frequently thermally stable at up to more than 250° C. and suitable for lubrication. The list of advantages provided by ionic liquid is long. Consequently, ionic liquids represent an environmentally friendly and resources-conserving replacement for the fluids described so far. A machine or pump according to the invention will comprise ionic liquid as the working fluid or operating fluid. The ionic liquid can possess one or a combination of two, three, four or more of the following properties: 1) a vapor pressure of less than 10^{-3} mbar; 2) a melting point of less than 20° C. or less than 100° C.; 3) a viscosity of no more than 1500 mPas and or between 50 and 400 mPas; 4) a flash point of no less than 150° C.; 5) a compressibility of no more than 0.7 volume loss per 100 bar; 7) an electric resistance of 0.25-4 kOhm*cm.

[0039] Additives can be used in combination with an ionic liquid according to the invention, such additives being those typically used in the oil and lubricant industry. Any zwitterionic or ionic commercial additive can be used. One or more additives can be used. Suitable additives include anti-wear additive, friction modifier, rust and corrosion inhibitor, antioxidant, dispersant, detergent, anti-foaming agent, pour point depressant and combinations thereof. Suitable additives are also disclosed in Patent No. [ADD] of Idemitsui, the disclosure of which is hereby incorporated by reference.

[0040] In the case of ionic liquids, a desired step-wise adjustment of the polarity and consequently a control of their properties, in particular their dissolution properties, is possible by the appropriate selection of cations and anions. The spectrum of ranges in this case from water-miscible ionic liquids via water-immiscible fluids to those which themselves form two phases even with organic solvents. Making skillful use of these extraordinary properties of ionic liquids is the key for the successful use of these fluids in the sense according to the invention.

[0041] The ionic liquid of the invention can be used in a variety of machinery and can be used as a substitute for engine oil, gear oil, hydraulic oil, cutting fluid (coolant), way lubricant, compressor oil, quenching and heat transfer oil, rust protection oil, transformer oil, turbine oil, chain lubricant, wire rope lubricant, bearing oil, sintered bearing oil, sealing oil.

[0042] By way of the use, provided for according to the invention, of an ionic liquid as operating liquid in processing and/or operating machines, it is possible to advantageously influence the following parameters as desired: a) the lubricating effect; b) the compressive rigidity; c) the viscosity as a function of the temperature; d) the vapour pressure limit; e) the chemical inertness; f) the thermal inertness; g) the solubility behaviour; h) the physiological safety.

[0043] In this way, it is possible to achieve the following advantages with ionic liquids which improve the above-mentioned parameters in comparison with the previously used operating liquids:

[0044] a. Reduction of the vacuum limit determined by the vacuum pressure. This is based on the fact that the extremely low vapour pressure of an ionic liquid of approximately 10^{-13} bar permits a substantial reduction of the achievable vacuum pressure, i.e. in the field of fluid of ring vacuum pumps, in the case of which an ionic liquid can be used, according to the invention, as ring liquid.

[0045] b. Any existing lubricating effect in combination with a higher temperature stability and a low vapour pressure leads to a lower lubricant consumption in the case of all types of lubricated vacuum pumps and compressors as well as to savings in oil separators while simultaneously reducing the achievable vacuum.

[0046] c. An achievable satisfactory lubrication effect in combination with physiological safety and thermal as well as chemical stability is a great additional bonus in terms of economy and safety regarding the lubricating requirements in hygiene operations and hygiene machines as well as equipment. Typical examples in this respect are hydraulic diaphragm pumps for hygiene operations, gears for hygiene operating facilities, requirements regarding bearing lubrication in hygiene operating facilities, gasket lubrication in hygiene operating facilities etc.

[0047] d. An increased compressive rigidity promises higher degrees of effectiveness in the case of all producers of pressure as a result of lower compressibility and consequently permits the use of smaller machines for the same conveying performance.

[0048] e. A less pronounced decrease in the viscosity with temperature increase allows more stable operating states and lesser leakage losses in pumps at elevated temperatures. This also increases the degree of effectiveness.

[0049] f. The low gas solubility and the very low vapour pressure of an ionic liquid allow its use according to the invention as a fluid piston for gases and certain fluids and as hydraulic fluid for diaphragm pumps with a low gas content and consequently an improved conveying accuracy. A special feature is that special ionic liquids are completely resistant to oxidation and can consequently be used for oxygen compression and as a fluid piston as lubricant.

[0050] g. The typical very low vapour pressure of an ionic allows greater suction height in the case of diaphragm pumps.

[0051] h. The chemical inertness of an ionic liquid allows the use as lubricant in conveying machines for chemicals.

[0052] Ionic liquids are therefore capable of avoiding the disadvantages described so far. Because of their extremely low vapour pressure of 10^{-13} bar (liquid salt), they are capable of reaching extremely low pressures in vacuum technology and consequently avoid contamination of the process gas both in vacuum pumps and in compressors.

[0053] In addition, there is the possibility of conveying, in this way, also critical gases, such as pure oxygen, in liquid-lubricated machines without causing oxidation or even fires.

[0054] As a result of the use of ionic liquids, anticipated according to the invention, in process machines it is now also possible to operate the above-mentioned piston machines with a fluid piston consisting of an ionic liquid and to avoid the disadvantages described at the same time. In this case, the use of ionic liquids also provides the advantage that a reaction with the substance conveyed is impossible since it is inert to a large extent.

[0055] Finally, it is also possible in the case of liquid ring vacuum pumps as a result of the use, according to the invention, of ionic liquids as ring liquid, to employ these pumps also in the fine vacuum range. In this way, liquid ring vacuum pumps can be used instead of the previously used screw compressors, piston compressors, rotary vane cell compressors etc. and their great advantages regarding robustness, reliability and process safety can fully be exploited.

[0056] The previously arising disadvantages and difficulties of prior art fluids and systems are avoided by the use, according to the invention, of ionic liquids since these can be adjusted to the process conditions concerned and the gasses to be sucked off.

[0057] Consequently, a reaction with the gas to be sucked off (evacuated or removed) can be safely prevented.

[0058] The advantages of the use of ionic liquids as operating liquid are explained in the following on the basis of the operating principle of a liquid ring vacuum pump and the limits of the fluids used for this purpose.

[0059] Thus a paddle wheel is arranged eccentrically in the case of a liquid ring vacuum pump in a cylindrical housing. The operating liquid present in the housing forms a co-rotating, concentrically formed fluid ring as a result of the rotation of the paddle wheel. Together with the rotor paddles, the fluid ring closes off the gas volumes in the chambers. As a result of the eccentricity of the rotor, the paddles immerse, in the upper area, completely into the fluid ring such that the chamber volume is completely filled with operating liquid. In the course of the rotation, the fluid ring detaches itself from the impeller hub and forms a crescent-shaped cavity. The gaseous fluid to be conveyed is sucked into the operating cavity by the control disc apertures arranged on the front surfaces on the impeller. Shortly before the gas-filled chamber volume reaches its maximum, the suction slit terminates and the chamber is sealed off by the control discs, the impeller paddles and the fluid. The fluid ring then migrates again towards the hub and compresses during this process the gas like a piston. As soon as the pressure slot apertures are reached, the compressed gas is pushed out.

[0060] The operating liquid needs to fulfill above all three functions in liquid ring vacuum pumps, namely firstly the function of a moving piston with the operating pulses of suction, compaction and pushing out, secondly the sealing function to seal the scoop cavities from each other and thirdly the absorption of heat of compression.

[0061] In order to discharge the heat of compression, part of the operating liquid is continually expelled through the pressure slot, the same amount of fresh fluid being fed in via a fluid channel in the shaft hub of the pump. As a result of this ongoing recooling, a constant temperature of the operating liquid is reached.

[0062] The vapour pressure of the operating liquid limits, the lowest possible suction level to be reached in the suction nipple of the pump. If the suction pressure drops to a value equal to or in the vicinity of the vapour pressure of the fluid, cavitation and consequently a complete drop in performance of the pump occur.

[0063] Only the invention provides a remedy by extending the field of application of the liquid ring vacuum pumps into the fine vacuum range as a result of the use of ionic liquids anticipated according to the invention. Since such ionic liquids do not have any vapour pressure worth noting, no cavitation occurs such that no restriction of the suction pressure downwards arises. Moreover, ionic liquids possess excellent lubricating properties and consequently allow a shaft seal to be provided which is adjusted to the fine vacuum. In contrast to the use of oil, substantially no contamination of the conveyed fluids arises whatsoever.

[0064] As a result of the use, anticipated according to the invention, of ionic liquids in processing machines, in particular in liquid ring vacuum pumps, their field of use is consequently extended into the fine vacuum range. Consequently, liquid ring vacuum pumps enter an area of application which had previously been covered by rotary vane pumps and exterior vane pumps, eccentric piston pumps or injectors. These, however, have the disadvantage that the necessary oil lubrication of the impeller leads to a contamination of the conveyed medium in the housing and that the discharge of the heat of compression can be achieved only by means of complex equipment.

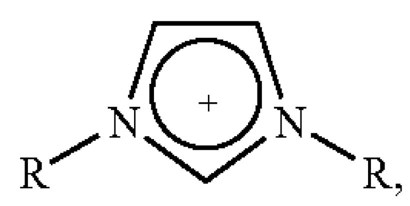
[0065] For this reason, liquid ring vacuum pumps can exhibit their pump-imminent advantages such as maximum reliability, quasi isothermic compression and absence of oil in the compression process in the now possible field of application of the fine vacuum (10^{-3}-10^{-1} mbar) and they open up, in this way, an entirely new way of process control and application possibilities.

[0066] The ionic liquids used according to the invention as operating liquid are compounds composed of cations and anions. The ionic liquid can comprise one such compound or a mixture of two or more such compounds. A cation can be selected from the group consisting of:

[0067] a quaternary ammonium-cation having the general formula $[NR^1R^2R^3R]^+$,

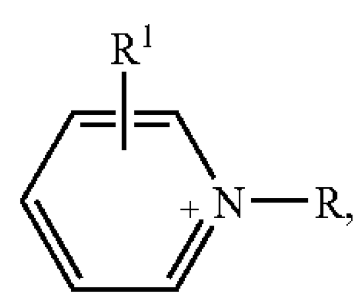
[0068] or a phosphonium cation having the general formula $[PR^1R^2R^3R]^+$,

[0069] or an imidazolium cation having the general formula



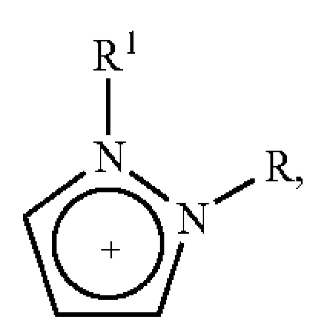
in which the imidazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl C_1-C_6 alkyl groups,

[0070] pyridinium cation having the general formula



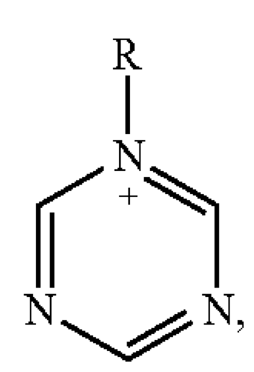
in which the pyridine nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups,

[0071] pyrazolium cation having the general formula



[0072] in which the pyrazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups, and

[0073] triazolium cation having the general formula



in which the triazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl C_1-C_6 alkyl groups, and

the radicals R^1, R^2, R^3 are selected independently from each other from the group consisting of:

[0074] hydrogen;

[0075] linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

[0076] heteroaryl groups, heteroaryl C_1-C_6 alkyl groups having 3 to 8 carbon atoms in the heteroaryl radical and at least one hetero atom selected from N, O and S, which can be substituted by at least one group selected from C_1-C_6 alkyl groups and/or halogen atoms; and

[0077] aryl groups, aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which, if necessary, may be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom; and

the radical R is selected from the group consisting of:

[0078] linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

[0079] heteroaryl C_1-C_6 alkyl group with 3 to 8 carbon atoms in the aryl radical and at least one hetero atom selected from N, O and S, which may be substituted by at least one C_1-C_6 alkyl group and/or halogen atoms; and

[0080] aryl-C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which may optionally be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom.

[0081] The anion can be selected from the group consisting of $[PF_6]^{31}$, $[BF_4]^-$, $[CF_3CO_2]^-$, $[CF_3SO_3]^-$, $[(CF_3SO_2)_2N]^-$, $[(CF_3SO_2)(CF_3COO)N]^-$, $[R^4—SO_3]^-$, $[R^4—O—SO_3]^-$, $[R^4—COO]^-$, Cl^-, Br^-, I^-, $[NO_3]^-$, $[N(CN)_2]^-$, $[HSO_4^-$ or $[R^4R^5PO_4]^-$, wherein:

the radicals R^4 and R^5 independently from each other are selected from the group consisting of:

[0082] hydrogen;

[0083] linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

[0084] heteroaryl groups, heteroaryl C_1-C_6 alkyl groups having 3 to 8 carbon atoms in the hetero aryl radical and at least one hetero atom selected from N, O and S which may be substituted by at least one group selected from C_1-C_6 alkyl groups and/or halogen atoms; and

[0085] aryl groups, aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which may be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom.

[0086] Some ionic liquids which exhibit the above-mentioned properties for certain desired application purposes are exemplarily mentioned below:

[0087] 1) 1-Butyl-3-methylimidazolium tetrafluoroborate: water-miscible, stable>250° C., chemically inert, positive lubricating properties;

[0088] 2) 1-Butyl-3-methylimidazolium hexafluorophosphate: not miscible with water, stable up to 250° C., chemically inert, positive lubricating properties;

[0089] 3) 1-Ethyl-3-methylimidazolium ethyl sulphate: miscible with water, physiologically safe (proven), stable up to 250° C., chemically inert, available on a ton scale;

[0090] 4) 1-Ethyl-3-methylimidazolium bistrifluoromethane sulfonyl amide: not miscible with water, stable >300° C., chemically inert, positive lubricating properties;

[0091] 5) 3-Methyl-1-ethylpyridinium ethyl sulphate: miscible with water, stable up to 250° C., chemically inert;

[0092] 6) Butyl trimethyl phosphonium dimethyl phosphate: miscible with water, stable up to 200° C., chemically inert.

[0093] Exemplary ionic liquids that can be used according to the invention include, without limitation, 1-alkyl-3-alkyl-imidazolium tetrafluoroborate, 1-alkyl-3-alkyl-imidazolium hexafluorophosphate, 1-alkyl-3-alkyl-imidazolium alkyl sulfate, 1-alkyl-3-alkyl-imidazolium alkyl sulfonate, 1-alkyl-3-alkyl-imidazolium Trifluoralkyl sulfonate, 1-alkyl-3-alkyl-imidazolium bistrifluoromethane sulfonyl amide, 1-alkyl-3-alkyl-imidazolium dialkyl phosphate, tetraalkylphosphonium dialkyl phosphate, 1-alkyl-3-alkyl-pyridinium tetrafluoroborate, 1-alkyl-3-alkyl-pyridinium hexafluorophosphate, 1-alkyl-3-alkyl-pyridinium alkyl sulfate, 1-alkyl-3-alkyl-pyridinium alkyl sulfonate, 1-alkyl-3-alkyl-pyridinium trifluoroalkyl sulfonate, 1-alkyl-3-alkyl-pyridinium bistrifluoromethane sulfonyl amide, 1-alkyl-3-alkyl-pyridinium dialkyl phosphate, N-alkyl-N-alkyl-pyrolidinium tetrafluoroborate, N-alkyl-N-alkyl-pyrolidinium hexafluorophosphate, N-alkyl-N-alkyl-pyrolidinium alkyl sulfate, N-alkyl-N-alkyl-pyrolidinium alkyl sulfonate, 1 N-alkyl-N-alkyl-pyrolidinium trifluoralkyl sulfonate, N-alkyl-N-alkyl-pyrolidinium bistrifluoromethane sulfonyl amide, N-alkyl-N-alkyl-pyrolidinium dialkyl phosphate, Trialkylsulfonium bistrifluoromethane sulfonyl amide. Combinations of two or more of the ionic liquids of the invention can be used. The alkyl moiety is independently substituted or unsubstituted at each occurrence in an ionic liquid. The alkyl component of the cation can be the same as or different than the alkyl component of the anion.

[0094] In view of the above description and the examples below, one of ordinary skill in the art will be able to practice the invention as claimed without undue experimentation. The foregoing will be better understood with reference to the following examples that detail certain procedures for the preparation of formulations according to the present invention. All references made to these examples are for the purposes of illustration. The following examples should not be considered exhaustive, but merely illustrative of only a few of the many embodiments contemplated by the present invention.

EXAMPLE 1

[0095] A machine is made to include an ionic liquid of the invention. A gas conveying machine (gas pump) is made to include an ionic liquid as a lubricating fluid and a barrier fluid. A reciprocating gas compressor is a suitable example. Exemplary gas conveying machines suitable for use according to the invention are disclosed in U.S. Pat. Nos. 7,255,540, No. 7,114,493, No. 7,083,395, No. 6,951,025, No. 6,663,359, No. 6,422,027, No. 6,382,923, No. 6,311,519, No. 6,227,266, No. 6,200,116, No. 6,193,680, No. 5,800,146, No. 5,785,501, No. 5,730,286, No. 5,593,288, No. 5,513,956, No. 5,490,429, No. 5,489,195, No. 5,413,001, No. 5,368,633, No. 5,356,275, No. 5,328,099, No. 5,217,352, No. 5,044,440, No. 4,984,974, No. 4,938,256, No. 4,881,455, No. 4,795,315, No. 4,764,085, No. 4,741,679, No. 4,741,417, No. 4,673,336, No. 4,638,674, No. 4,589,494, No. 4,584,878, No. 4,562,702, No. 4,524,587, No. 4,498,844, No. 4,405,291, No. 4,355,789, No. 4,267,827, No. 4,257,751, No. 4,236,917, No. 4,097,201, and No. 4,080,107, the entire disclosures of which are hereby incorporated by reference.

EXAMPLE 2

[0096] A Hydraulic diaphragm pump is made to include an ionic liquid as the hydraulic fluid. Exemplary hydraulic diaphragm pumps suitable for use according to the invention are disclosed in U.S. Pat. Nos. 6,889,765, No. 6,884,045, No. 6,595,280, No. 6,464,474, No. 6,419,841, No. 6,251,293, No. 6,129,525, No. 6,105,829, No. 6,099,269, No. 6,071,089, No. 6,017,198, No. 5,934,886, No. 5,810,567, No. 5,782,315, No. 5,772,899, No. 5,707,219, No. 5,547,351, No. 5,516,429, No. 5,306,122, No. 5,246,351, No. 5,244,360, No. 5,192,198, No. 5,167,837, No. 5,073,092, No. 4,966,528, No. 4,950,134, No. 4,934,906, No. 4,865,528, No. 4,818,191, No. 4,749,342, No. 4,634,351, No. 4,619,589, No. 4,604,037, No. 4,580,952, No. 4,573,885, No. 4,540,346, No. 4,474,540, No. 4,465,438, No. 4,181,615, No. 4,131,397, No. 4,050,859, No. 4,019,837, No. 4,019,335, No. 3,972,654, and No. 3,957,399, the entire disclosures of which are hereby incorporated by reference.

EXAMPLE 3

[0097] A liquid ring vacuum pump is made to include an ionic liquid as the ring liquid. Exemplary liquid ring vacuum pumps suitable for use according to the invention are disclosed in U.S. Pat. Nos. 6,585,492, No. 6,350,299, No. 6,315,524, No. 6,149,345, No. 6,128,901, No. 6,106,239, No. 6,033,462, No. 6,013,138, No. 5,946,767, No. 5,860,767, No. 5,803,713, No. 5,688,076, No. 5,586,836, No. 5,423,614, No. 5,366,348, No. 5,290,152, No. 5,246,348, No. 5,222,869, No. 5,151,010, No. 5,116,198, No. 5,078,573, No. 4,946,349, No. 4,753,016, No. 4,692,101, No. 4,657,487, No. 4,613,283, No. 4,554,055, No. 4,545,730, No. 4,505,645, No. 4,484,457, No. 4,225,288, and No. 4,172,694, the entire disclosures of which are hereby incorporated by reference.

EXAMPLE 4

[0098] A machine comprising a piston oscillating in a cylinder, in the form of a fluid piston or a fluid master piston arranged in front, is made to include an ionic liquid and, as a result of its oscillating movement, conveys a gas and/or non-miscible fluid of low density or a fluid of high density. Exemplary machines comprising a fluid piston or fluid master piston suitable for use according to the invention are disclosed in U.S. Pat. Nos. 7,162,944, No. 7,048,095, No. 6,945,889, No. 6,279,702, No. 3,067,726, No. 3,980,231, No. 5,395,201, No. 4,529,181 and No. 7,171,888 Canadian Patent No. 1,209,405, and PCT International Publications No. WO 1994/027852, No. WO 1994/023201, WO 1998/001405, and No. WO 2007/-40599, the entire disclosures of which are hereby incorporated by reference.

EXAMPLE 5

[0099] A screw pump is made to include an ionic liquid according to the invention.

[0100] Exemplary screw pumps suitable for use according to the invention are disclosed in U.S. Pat. Nos. 7,234,925, No. 7,232,297, No. 7,165,933, No. 7,131,827, No. 7,093,665, No. 7,080,798, No. 6,877,967, No. 6,854,955, No. 6,716,008, No. 6,688,499, No. 6,666,672, No. 6,600,000, No. 6,554,799, No. 6,544,015, No. 6,537,049, No. 6,497,563, No. 6,457,950, No. 6,447,275, No. 6,241,486, No. 6,227,829, No. 6,079,797, No. 5,953,567, No. 5,934,891, No. 5,779,451, No. 5,769,618, No. 5,738,505, No. 5,624,249, No. 5,472,319, No. 5,395,225, No. 5,358,390, No. 5,348,453, No. 5,295,788, No. 5,195,880, No. 5,102,294, No. 5,073,082, No. 5,046,666, No. 5,044,906, No. 5,015,162, No. 4,990,070, No. 4,942,944, No. 4,778,080, No. 4,773,837, No. 4,772,177, No. 4,591,322, No. 4,580,955, No. 4,580,953, No. 4,566,640, No. 4,491,374, No. 4,318,670, No. 4,239,449, No. 4,104,009, No. 4,047,858, No. 4,028,025, and No. 4,018,549, the entire disclosures of which are hereby incorporated by reference.

We claim:

1. An operating machine selected from the group consisting of:

a) a gas conveying machine characterized in that it comprises an ionic liquid as lubricating and barrier fluid;

b) a hydraulic diaphragm pump characterized in that it comprises an ionic liquid as hydraulic fluid;

c) a liquid ring vacuum pump characterized in that it comprises an ionic liquid as ring liquid; and

d) a piston machine characterized in that it is equipped with a piston, oscillating in a cylinder, in the form of a fluid piston or a fluid master piston arranged in front which fluid comprises an ionic liquid and, as a result of its oscillating movement, conveys a gas and/or non-miscible fluid of low density or a fluid of high density.

2. (canceled)

3. (canceled)

4. (canceled)

5. The operating machine of claim 1, all limitations of which are incorporated by reference, characterized in that the ionic liquid is a compound, or mixture of two or more compounds, of the formula

[cation][anion],

wherein: cation is selected from the group consisting of:

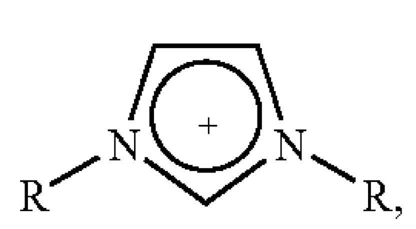
a quaternary ammonium cation having the general formula

$[NR^1R^2R^3R]^+$,

or a phosphonium cation having the general formula

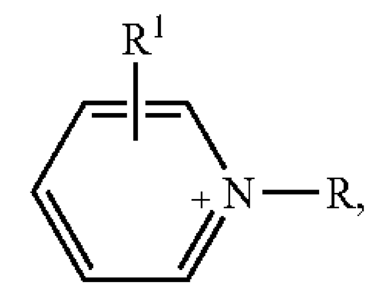
$[PR^1R^2R^3R]^+$,

or an imidazolium cation having the general formula



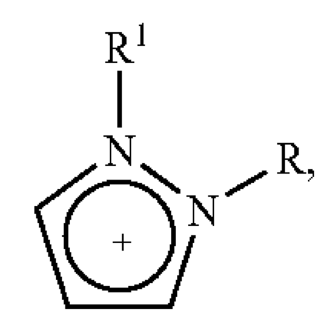
in which the imidazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl C_1-C_6 alkyl groups,

pyridinium cation having the general formula



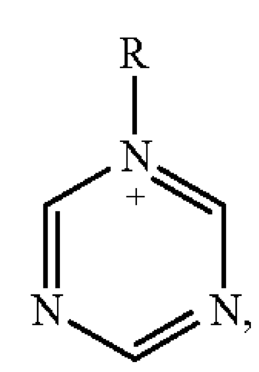
in which the pyridine nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups,

pyrazolium cation having the general formula



in which the pyrazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups, and

triazolium cation having the general formula



in which the triazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups, and

the radicals R^1, R^2, R^3 independently from each other are selected from the group consisting of:

hydrogen;

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl groups, heteroaryl C_1-C_6 alkyl groups having 3 to 8 carbon atoms in the heteroaryl radical and at least one hetero atom selected from N, O and S, which can be substituted by at least one group selected from C_1-C_6 alkyl groups and/or halogen atoms; and

aryl groups, aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which, if necessary, may be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom; and

the radical R is selected from

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl C_1-C_6 alkyl group with 3 to 8 carbon atoms in the aryl radical and at least one hetero atom selected from N, O and S, which may be substituted by at least one C_1-C_6 alkyl group and/or halogen atoms;

aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which may optionally be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom; and

anion is selected from the group consisting of $[PF_6]^-$, $[BF_4]^-$, $[CF_3CO_2]^-$, $[CF_3SO_3]^-$, $[(CF_3SO_2)_2N]^-$, $[(CF_3SO_2)(CF_3COO)N]^-$, $[R^4—SO_3]^-$, $[R^4—O—SO_3]^-$, $[R^4—COO]^-$, Cl^-, Br^-, I^-, $[NO_3]^-$, $[N(CN)_2]^-$, $[HSO_4]^-$ and $[R^4R^5PO_4]^-$, wherein:

the radicals R^4 and R^5 independently from each other are selected from the group consisting of:

hydrogen;

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl groups, heteroaryl C_1-C_6 alkyl groups having 3 to 8 carbon atoms in the hetero aryl radical and at least one hetero atom selected from N, O and S which may be substituted by at least one group selected from C_1-C_6 alkyl groups and/or halogen atoms; and

aryl groups, aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which may be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom.

6. The operating machine according to claim 5, all limitations of which are incorporated by reference, characterized in that the ionic liquid used as operating liquid is selected from the group consisting of 1-butyl-3-methylimidazolium tetrafluoroborate, 1-butyl-3-methylimidazolium hexafluorophosphate, 1-ethyl-3-methylimidazolium ethyl sulphate, 1-ethyl-3-methylimidazolium bistrifluoromethane sulfonyl amide, 3-methyl-1-ethylpyridinium ethyl sulphate, and butyl trimethyl phosphonium dimethyl phosphate or a combination or two or more thereof.

7. The operating machine according to claim 5, all limitations of which are incorporated by reference, characterized in that the ionic liquid used as operating liquid is selected from the group consisting 1-alkyl-3-alkyl-imidazolium tetrafluoroborate, 1-alkyl-3-alkyl-imidazolium hexafluorophosphate, 1-alkyl-3-alkyl-imidazolium alkyl sulfate, 1-alkyl-3-alkyl-imidazolium alkyl sulfonate, 1-alkyl-3-alkyl-imidazolium trifluoroalkyl sulfonate, 1-alkyl-3-alkyl-imidazolium bistrifluoromethane sulfonyl amide, 1-alkyl-3-alkyl-imidazolium dialkyl phosphate, tetraalkylphosphonium dialkyl phosphate, 1-alkyl-3-alkyl-pyridinium tetrafluoroborate, 1-alkyl-3-alkyl-pyridinium hexafluorophosphate, 1-alkyl-3-alkyl-pyridinium alkyl sulfate, 1-alkyl-3-alkyl-pyridinium alkyl sulfonate, 1-alkyl-3-alkyl-pyridinium trifluoroalkyl sulfonate, 1-alkyl-3-alkyl-pyridinium bistrifluoromethane sulfonyl amide, 1-alkyl-3-alkyl-pyridinium dialkyl phosphate, N-alkyl-N-alkyl-pyrolidinium tetrafluoroborate, N-alkyl-N-alkyl-pyrolidinium hexafluorophosphate, N-alkyl-N-alkyl-pyrolidinium alkyl sulfate, N-alkyl-N-alkyl-pyrolidinium alkyl sulfonate, 1 N-alkyl-N-alkyl-pyrolidinium trifluoroalkyl sulfonate, N-alkyl-N-alkyl-pyrolidinium bistrifluoromethane sulfonyl amide, N-alkyl-N-alkyl-pyrolidinium dialkyl phosphate, trialkylsulfonium bistrifluoromethane sulfonyl amide, and a combination of two or more thereof.

8. The operating machine according to claim 5, all limitations of which are incorporated by reference, wherein the ionic liquid possesses one or a combination of two, three, four or more of the following properties: a) a vapor pressure of less than 10^{-3} mbar; b) a melting point of less than 20° C. or less than 100° C.; c) a viscosity of no more than 1500 mPas and or between 50 and 400 mPas; d) a flash point of no less than 150° C.; e) a compressibility of no more than 0.7 volume loss per 100 bar; f) an electric resistance of 0.25-4 kOhm*cm.

9. The operating machine according to claim 5, all limitations of which are incorporated by reference, wherein the ionic liquid further comprises one or more additives selected from the group consisting of anti-wear additive, friction modifier, rust and corrosion inhibitor, antioxidant, dispersant, detergent, anti-foaming agent, and pour point depressant.

10. A method of employing an operating liquid in a gas conveying machine, hydraulic diaphragm pump, liquid ring vacuum pump screw pump, or piston-containing machine comprising employing an ionic liquid as the operating liquid, whereby the ionic liquid serves as a lubricating fluid, barrier fluid, sealing fluid, hydraulic fluid, ring liquid, fluid piston and/or pressure transfer fluid.

11. The method of claim 10, all limitations of which are incorporated by reference, characterized in that the ionic liquid is used in a gas conveying machine as a lubricating fluid and barrier fluid.

12. The method of claim 10, all limitations of which are incorporated by reference, characterized in that the ionic liquid is used in a hydraulic diaphragm pump as a hydraulic fluid.

13. The method of claim 10, all limitations of which are incorporated by reference, characterized in that the ionic liquid is used in a liquid ring vacuum pump as a ring liquid, thereby extending the operating range of the pump into the fine vacuum range.

14. The method of claim 10, all limitations of which are incorporated by reference, characterized in that the ionic liquid is used in a piston-containing machine as a fluid piston oscillating in a cylinder which, as a result of its oscillating movement, is capable of conveying a gas and/or a non-miscible fluid of low density or a fluid of high density.

15. A method of equipping a machine comprising: including an ionic liquid in the machine as an operating fluid in the machine, wherein: the machine is selected from the group consisting of gas conveying machine, hydraulic diaphragm pump, liquid ring vacuum pump, screw pump, and piston-containing machine; and the ionic liquid serves as a lubricating fluid, barrier fluid, sealing fluid, hydraulic fluid, ring liquid, fluid piston and/or pressure transfer fluid.

16. The method according to claim 10, all limitations of which are incorporated by reference, wherein the ionic liquid is a compound, or mixture of two or more compounds, of the formula

[cation][anion],

wherein: cation is selected from the group consisting of:

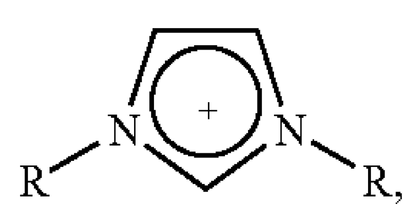
a quaternary ammonium cation having the general formula

$[NR^1R^2R^3R]^+$,

or a phosphonium cation having the general formula

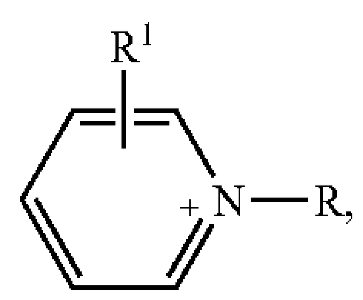
$[PR^1R^2R^3R]^+$,

or an imidazolium cation having the general formula



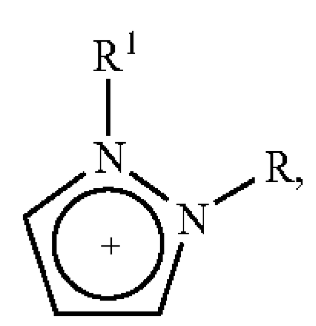
in which the imidazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl C_1-C_6 alkyl groups,

pyridinium cations having the general formula



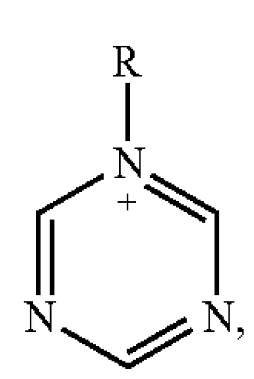
in which the pyridine nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups,

pyrazolium cations having the general formula



in which the pyrazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-Cl-C_6 alkyl groups,

and triazolium cations having the general formula



in which the triazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups,

and the radicals R^1, R^2, R^3 independently from each other are selected from the group consisting of:

hydrogen;

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl groups, heteroaryl C_1-C_6 alkyl groups having 3 to 8 carbon atoms in the heteroaryl radical and at least one hetero atom selected from N, O and S, which can be substituted by at least one group selected from C_1-C_6 alkyl groups and/or halogen atoms; and

aryl groups, aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which, if necessary, may be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom; and

the radical R is selected from

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl C_1-C_6 alkyl group with 3 to 8 carbon atoms in the aryl radical and at least one hetero atom selected from N, O and S, which may be substituted by at least one C_1-C_6 alkyl group and/or halogen atoms;

aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which may optionally be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom; and

anion is selected from the group consisting of $[PF_6]^-$, $[BF_4]^-$, $[CF_3CO_2]^-$, $[CF_3SO_3]^-$, $[(CF_3SO_2)_2N]^-$, $[(CF_3SO_2)(CF_3COO)N]^-$, $[R^4\text{—}SO_3]^-$, $[R^4\text{—}O\text{—}SO_3]^-$, $[R^4\text{—}COO]^{31}$, Cl^-, Br^-, I^-, $[NO_3]^-$, $[N(CN)_2]^-$, $[HSO_4]^-$ and $[R^4R^5PO_4]^-$, wherein:

the radicals R^4 and R^5 independently from each other are selected from the group consisting of:

hydrogen;

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl groups, heteroaryl C_1-C_6 alkyl groups having 3 to 8 carbon atoms in the hetero aryl radical and at least one hetero atom selected from N, O and S which may be substituted by at least one group selected from C_1-C_6 alkyl groups and/or halogen atoms; and

aryl groups, aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which may be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom.

17. The method according to claim 16, all limitations of which are incorporated by reference, characterized in that the ionic liquid is selected from the group consisting of 1-butyl-3-methylimidazolium tetrafluoroborate, 1-butyl-3-methylimidazolium hexafluorophosphate, 1-ethyl-3-methylimidazolium ethyl sulphate, 1-ethyl-3-methylimidazolium bistrifluoromethane sulfonyl amide, 3-methyl-1-ethyl-pyridinium ethyl sulphate, and butyl trimethyl phosphonium dimethyl phosphate or a combination of two or more thereof.

18. The method according to claim 16, all limitations of which are incorporated by reference, characterized in that the ionic liquid is selected from the group consisting 1-alkyl-3-alkyl-imidazolium tetrafluoroborate, 1-alkyl-3-alkyl-imidazolium hexafluorophosphate, 1-alkyl-3-alkyl-imidazolium alkyl sulfate, 1-alkyl-3-alkyl-imidazolium alkyl sulfonate, 1-alkyl-3-alkyl-imidazolium trifluoroalkyl sulfonate, 1-alkyl-3-alkyl-imidazolium bistrifluoromethane sulfonyl amide, 1-alkyl-3-alkyl-imidazolium dialkyl phosphate, tetraalkylphosphonium dialkyl phosphate, 1-alkyl-3-alkyl-pyridinium tetrafluoroborate, 1-alkyl-3-alkyl-pyridinium hexafluorophosphate, 1-alkyl-3-alkyl-pyridinium alkyl sulfate, 1-alkyl-3-alkyl-pyridinium alkyl sulfonate, 1-alkyl-3-alkyl-pyridinium trifluoroalkyl sulfonate, 1-alkyl-3-alkyl-pyridinium bistrifluoromethane sulfonyl amide, 1-alkyl-3-alkyl-pyridinium dialkyl phosphate, N-alkyl-N-alkyl-pyrolidinium tetrafluoroborate, N-alkyl-N-alkyl-pyrolidinium hexafluorophosphate, N-alkyl-N-alkyl-pyrolidinium alkyl sulfate, N-alkyl-N-alkyl-pyrolidinium alkyl sulfonate, 1 N-alkyl-N-alkyl-pyrolidinium trifluoroalkyl sulfonate, N-alkyl-N-alkyl-pyrolidinium bistrifluoromethane sulfonyl amide, N-alkyl-N-alkyl-pyrolidinium dialkyl phosphate, trialkylsulfonium bistrifluoromethane sulfonyl amide, and a combination of two or more thereof.

19. The method according to claim 16, all limitations of which are incorporated by reference, wherein the ionic liquid possesses one or a combination of two, three, four or more of the following properties: a) a vapor pressure of less than 10-3 mbar; b) a melting point of less than 20° C. or less than 100° C.; c) a viscosity of no more than 1500 mPas and or between 50 and 400 mPas; d) a flash point of no less than 150° C.;

e) a compressibility of no more than 0.7 volume loss per 100 bar; f) an electric resistance of 0.25-4 kOhm*cm.

20. The method according to claim 16, all limitations of which are incorporated by reference, wherein the ionic liquid further comprises one or more additives selected from the group consisting of anti-wear additive, friction modifier, rust and corrosion inhibitor, antioxidant, dispersant, detergent, anti-foaming agent, and pour point depressant.

21. The method according to claim 15, wherein the ionic liquid is a compound, or mixture of two or more compounds, of the formula

[cation][anion],

wherein:

cation is selected from the group consisting of:

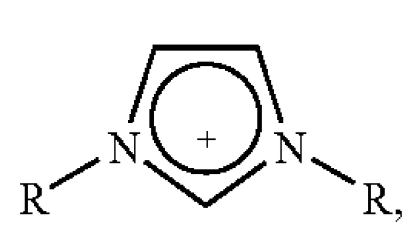
a quaternary ammonium cation having the general formula

$[NR^1R^2R^3R]^+$,

or a phosphonium cation having the general formula

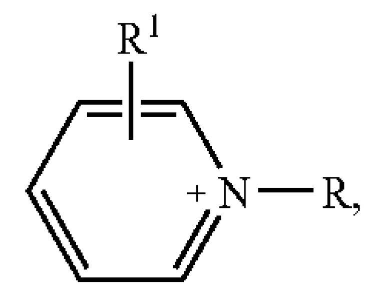
$[PR^1R^2R^3R]^+$,

or an imidazolium cation having the general formula



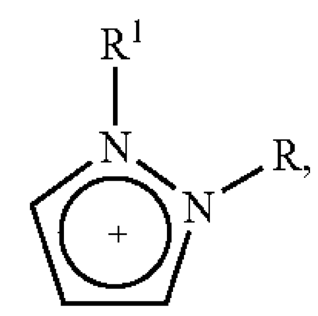
in which the imidazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl C_1-C_6 alkyl groups,

pyridinium cations having the general formula



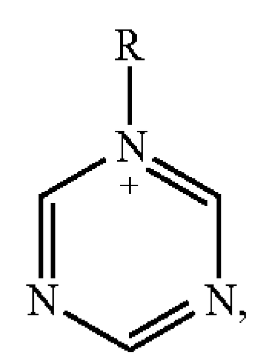
in which the pyridine nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups,

pyrazolium cations having the general formula



in which the pyrazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups,

and triazolium cations having the general formula



in which the triazole nucleus may be substituted by at least one group selected from C_1-C_6 alkyl groups, C_1-C_6 alkoxy groups, C_1-C_6 aminoalkyl groups, C_5-C_{12} aryl groups or C_5-C_{12} aryl-C_1-C_6 alkyl groups,

and the radicals R^1, R^2, R^3 independently from each other are selected from the group consisting of:

hydrogen;

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl groups, heteroaryl C_1-C_6 alkyl groups having 3 to 8 carbon atoms in the heteroaryl radical and at least one hetero atom selected from N, O and S, which can be substituted by at least one group selected from C_1-C_6 alkyl groups and/or halogen atoms; and aryl groups, aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which, if necessary, may be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom; and

the radical R is selected from

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl C_1-C_6 alkyl group with 3 to 8 carbon atoms in the aryl radical and at least one hetero atom selected from N, O and S, which may be substituted by at least one C_1-C_6 alkyl group and/or halogen atoms;

aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which may optionally be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom; and

anion is selected from the group consisting of $[PF_6]^-$, $[BF_4]^-$, $[CF_3CO_2]^-$, $[CF_3SO_3]^-$, $[(CF_3SO_2)_2N]^-$, $[(CF_3SO_2)(CF_3COO)N]^-$, $[R^4—SO_3]^-$, $[R^4—O—SO_3]^-$, $[R^4—COO]^-$, Cl^-, Br^-, I^-, $[NO_3]^-$, $[N(CN)_2]^-$, $[HSO_4]^-$ and $[R^4R^5PO_4]^-$, wherein:

the radicals R^4 and R^5 independently from each other are selected from the group consisting of:

hydrogen;

linear or branched, saturated or unsaturated, aliphatic or alicyclic alkyl groups having 1 to 20 carbon atoms;

heteroaryl groups, heteroaryl C_1-C_6 alkyl groups having 3 to 8 carbon atoms in the hetero aryl radical and at least one hetero atom selected from N, O and S which may be substituted by at least one group selected from C_1-C_6 alkyl groups and/or halogen atoms; and

aryl groups, aryl C_1-C_6 alkyl groups having 5 to 12 carbon atoms in the aryl radical which may be substituted by at least one C_1-C_6 alkyl group and/or a halogen atom.

22. The method according to claim 21, all limitations of which are incorporated by reference, characterized in that the ionic liquid is selected from the group consisting of 1-butyl-3-methylimidazolium tetrafluoroborate, 1-butyl-3-methylimidazolium hexa-fluorophosphate, 1-ethyl-3-methylimidazolium ethyl sulphate, 1-ethyl-3-methylimidazolium bistrifluoromethane sulfonyl amide, 3-methyl-1-ethylpyridinium ethyl sulphate, and butyl trimethyl phosphonium dimethyl phosphate or a combination of two or more thereof.

23. The method according to claim 21, all limitations of which are incorporated by reference, characterized in that the ionic liquid is selected from the group consisting 1-alkyl-3-alkyl-imidazolium tetrafluoroborate, 1-alkyl-3-alkyl-imidazolium hexafluorophosphate, 1-alkyl-3-alkyl-imidazolium alkyl sulfate, 1-alkyl-3-alkyl-imidazolium alkyl sulfonate, 1-alkyl-3-alkyl-imidazolium trifluoroalkyl sulfonate, 1-alkyl-3-alkyl-imidazolium bistrifluoromethane sulfonyl amide, 1-alkyl-3-alkyl-imidazolium dialkyl phosphate, tetraalkylphosphonium dialkyl phosphate, 1-alkyl-3-alkyl-pyridinium tetrafluoroborate, 1-alkyl-3-alkyl-pyridinium hexafluorophosphate, 1-alkyl-3-alkyl-pyridinium alkyl sulfate, 1-alkyl-3-alkyl- pyridinium alkyl sulfonate, 1-alkyl-3-alkyl-pyridinium trifluoroalkyl sulfonate, 1-alkyl-3-alkyl-pyridinium bistrifluoromethane sulfonyl amide, 1-alkyl-3-alkyl-pyridinium dialkyl phosphate, N-alkyl-N-alkyl-pyrolidinium tetrafluoroborate, N-alkyl-N-alkyl-pyrolidinium hexafluorophosphate, N-alkyl-N-alkyl-pyrolidinium alkyl sulfate, N-alkyl-N-alkyl-pyrolidinium alkyl sulfonate, 1 N-alkyl-N-alkyl-pyrolidinium trifluoroalkyl sulfonate, N-alkyl-N-alkyl-pyrolidinium bistrifluoromethane sulfonyl amide, N-alkyl-N-alkyl-pyrolidinium dialkyl phosphate, trialkylsulfonium bistrifluoromethane sulfonyl amide, and a combination of two or more thereof.

24. The method according to claim 21, all limitations of which are incorporated by reference, wherein the ionic liquid possesses one or a combination of two, three, four or more of the following properties: a) a vapor pressure of less than 10^{-3} mbar; b) a melting point of less than 20° C. or less than 100° C.; c) a viscosity of no more than 1500 mPas and or between 50 and 400 mPas; d) a flash point of no less than 150° C.; e) a compressibility of no more than 0.7 volume loss per 100 bar; f) an electric resistance of 0.25-4 kOhm*cm.

25. The method according to claim 21, all limitations of which are incorporated by reference, wherein the ionic liquid further comprises one or more additives selected from the group consisting of anti-wear additive, friction modifier, rust and corrosion inhibitor, antioxidant, dispersant, detergent, anti-foaming agent, and pour point depressant.

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