

## **Process for dehumidifying moist gas mixtures**

The invention relates to a process for dehumidifying a moist gas mixture. The invention further relates to an apparatus for dehumidifying a moist gas mixture and to the use of said apparatus in the process according to the invention.

### **5 Background of the invention**

Dehumidification of moist gas mixtures is necessary in a multitude of technical fields.

For instance ventilation and air conditioning of buildings or vehicles generally necessitates not only cooling but also dehumidification of the air since the air to be cooled is often so humid that during cooling to the desired temperature the temperature falls below the dew point temperature. Hence in  
 10 conventional air conditioning systems dehumidification of the air accounts for a large part of the electricity consumption.

The electricity consumption of air conditioning systems for buildings is reduced by dehumidifying the air by adsorption or absorption of water with a drying medium and subsequently regenerating the water-laden drying medium by heating to a temperature at which the water is desorbed again.  
 15 Compared to adsorption on a solid adsorbent, the advantage of absorption in a liquid absorption medium is that air dehumidification can be carried out with reduced equipment complexity and with less drying medium and that regeneration of the water-laden drying medium using solar heat is easier to carry out.

A further technical field where dehumidifying of moist gas mixtures is employed is the field of  
 20 absorption chillers (also known as "absorption heat pump", principle described in WO 2014/079675 A1). Here, the moist gas mixture is formed during evaporation of water under low pressure. The water vapour thus formed needs to be removed from the moist gas mixture so that said mixture may then be returned to the water evaporation to pass through a new cycle. Here too, absorption in a liquid absorption medium is favoured over adsorption on a solid adsorption medium.

25 Finally, dehumidification of moist gas mixtures is also important in the field of natural gas extraction, as described in DE 10 2010 004 779 A1 for example.

Examples of the materials typically incorporated in air or natural gas dehumidifying plants and in chillers include titanium, copper and noble metals.

The aqueous solutions of lithium bromide, lithium chloride or calcium chloride hitherto employed as  
 30 liquid absorption media in commercial air conditioning systems have the disadvantage that they are corrosive towards the metallic materials of construction typically employed in air conditioning systems and that they thus necessitate the use of expensive special materials of construction. This problem is also encountered with steel and stainless steel. These solutions can additionally cause problems due to salt crystallizing out of the absorption medium.

Y. Luo et al., Appl. Thermal Eng. 31 (2011) 2772-2777 proposes using the ionic liquid 1-ethyl-3-methylimidazolium tetrafluoroborate in place of aqueous solutions of lithium bromide for air dehumidification. However, this ionic liquid has the disadvantage of only poor absorption capability.

Y. Luo et al., Solar Energy 86 (2012) 2718-2724 proposes the ionic liquid 1,3-dimethylimidazolium acetate as an alternative to 1-ethyl-3-methylimidazolium tetrafluoroborate for air dehumidification. However, 1,3-dimethylimidazolium acetate is not stable and decomposes to a not inconsiderable extent during desorption.

This problem is also encountered for the ionic liquids proposed in US 2011/0247494 A1, paragraph [0145]. This document proposes using trimethylammonium acetate or 1-ethyl-3-methylimidazolium acetate as liquid drying agent in place of aqueous lithium chloride solution. Example 3 compares water uptake from humid air for a series of further ionic liquids.

CN 102335545 A describes aqueous solutions of ionic liquids that do not suffer from the abovementioned problems as absorption media for air dehumidification. CN 102335545 A chiefly describes steel-based air dehumidifiers. Ionic liquids described are, inter alia, 1,3-dimethylimidazolium dimethyl phosphate, 1-ethyl-3-methylimidazolium dimethyl phosphate and 1-butyl-3-methylimidazolium dimethyl phosphate. The absorption media are reported to be noncorrosive toward steel. However, heat transfer, which is important for efficient air dehumidification, is relatively low with the ionic liquids cited in CN 102335545 A in steel-based apparatuses.

Yet, heat transfer is an important parameter which must be accounted for when choosing absorption media. Thus, in the field of air dehumidification absorption media which ensure a particularly good heat transfer between themselves and further constituents of an air dehumidifier are particularly readily employable. In air dehumidifiers in which metallic components (for example steel) are employed this heat transfer takes place at least partially between the absorption media and metallic surfaces.

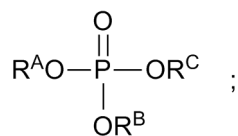
The present invention accordingly has for its object the provision of absorption media that ensure better heat transfer than prior art absorption media when used in steel-based air conditioning systems, air dehumidifiers, absorption chillers etc.

Absorption media which achieve this object have now surprisingly been found.

### **Detailed description of the invention**

The present invention accordingly relates in a first aspect to a process for dehumidifying a moist gas mixture **G**, in particular moist air, in an apparatus **V**<sub>1</sub>, comprising the steps of:

- (a) contacting the moist gas mixture **G** with an aqueous liquid absorption medium **A**<sub>VE</sub> comprising a mixture of at least one trialkyl phosphate of structure **(I)** where



(I)

and at least one salt **S** selected from the group consisting of  $\text{Q}^+\text{A}^-$ ,  $\text{Q}^+(\text{R}^1\text{O})_2\text{PO}_2^-$ ,  $(\text{Q}^+)_2\text{R}^2\text{OPO}_3^{2-}$ ,  $\text{Q}^+\text{M}^+\text{R}^3\text{OPO}_3^{2-}$ ,

wherein **A<sub>VE</sub>** at least partially absorbs water from the moist gas mixture **G**,

5 to afford an aqueous liquid absorption medium **A<sub>VE1</sub>** having an elevated water content compared to **A<sub>VE</sub>** and a gas mixture **G<sub>1</sub>** having a relatively low water content compared to the moist gas mixture **G**,

(b) partially removing water from **A<sub>VE1</sub>** to obtain an aqueous liquid absorption medium **A<sub>VE2</sub>** having a relatively low water content compared to **A<sub>VE1</sub>**,

10 wherein the apparatus **V<sub>1</sub>** at least partially comprises a surface made of a steel material of construction **O<sub>st</sub>** and in the apparatus **V<sub>1</sub>** at least one of **A<sub>VE</sub>**, **A<sub>VE1</sub>**, **A<sub>VE2</sub>** contacts the surface made of a steel material of construction **O<sub>st</sub>** via at least one contact surface,

characterized in that

15 **Q<sup>+</sup>** is a dialkylimidazolium cation in which in particular the alkyl groups each independently of one another have 1 to 10 carbon atoms,

wherein **A<sup>-</sup>** is an anion selected from the group consisting of  $\text{R}^*\text{COO}^-$ ,  $\text{R}'\text{SO}_3^-$ ,  $\text{HSO}_4^-$ ,  $\text{R}''\text{SO}_4^-$ , wherein **R<sup>\*</sup>**, **R'**, **R''**, **R<sup>A</sup>**, **R<sup>B</sup>**, **R<sup>C</sup>**, **R<sup>1</sup>**, **R<sup>2</sup>**, **R<sup>3</sup>** are each independently of one another an alkyl group, in particular having 1 to 10, preferably 1 to 8, more preferably 1 to 6, yet more preferably 1 to 4, still more preferably 1 to 2, carbon atoms

20 and wherein **M<sup>+</sup>** is an alkali metal ion, preferably **Li<sup>+</sup>**, **K<sup>+</sup>** or **Na<sup>+</sup>**, yet more preferably **K<sup>+</sup>** or **Na<sup>+</sup>**.

The moist gas mixture **G** employed in the process is not particularly restricted. "Moist" is to be understood as meaning in the context of the invention "comprising water, in particular water vapour".

25 "Aqueous" is to be understood as meaning that the particular solution (i.e. in the case of the aqueous liquid absorption media said absorption media) comprises water.

"Dehumidifying" is to be understood as meaning at least partially removing water.

"At least partially" is to be understood as meaning in the context of the invention "partially or completely".

30 "Moist gas mixture **G**" is accordingly to be understood as meaning in the context of the invention that the gas mixture **G** comprises water, preferably water vapour ("water vapour" is to be understood as meaning water in the gaseous physical state), and that its composition is otherwise

not particularly restricted. The water content of this moist gas mixture is not particularly restricted and is in particular from 0.01 vol% - 99.99 vol% ("vol%" indicates the volume of water vapour based on the overall volume of moist gas mixture **G**). The composition of the moist gas **G** may otherwise vary depending on the application of the process according to the invention. The moist  
 5 gas mixture **G** is in particular selected from moist natural gas, moist air (this may be moist indoor air or the moist air resulting from evaporation of water in absorption chillers), preferably moist air. For moist natural gas the water content is in particular from 0.01 vol% to 15.00 vol%, for moist air said content is in particular from 0.01 vol% to 15.00 vol% in the case of moist indoor air or in particular from 95.00 vol% to 99.99 vol% which is the preferred range when moist air resulting from  
 10 evaporation of water in absorption chillers is concerned.

The process according to the invention is carried out in an apparatus **V<sub>1</sub>** which at least partially comprises a surface made of a steel material of construction **O<sub>st</sub>** (in the context of the invention **O<sub>st</sub>** is short for "surface made of a steel material of construction") and in which at least one of the aqueous liquid absorption media selected from the group consisting of **A<sub>VE</sub>**, **A<sub>VE1</sub>**, **A<sub>VE2</sub>** contacts the  
 15 surface made of a steel material of construction **O<sub>st</sub>** via at least one contact surface.

In particular, an apparatus **V<sub>1</sub>** having the following components may be employed:

- (i) at least one water absorption unit **W<sub>abs1</sub>** set up for contacting the moist gas mixture with the aqueous liquid absorption medium **A<sub>VE</sub>**,
- (ii) at least one water desorption unit **W<sub>des1</sub>** which comprises a heat exchanger **W<sub>x1</sub>** and is set  
 20 up for at least partially removing water from an aqueous liquid absorption medium **A<sub>VE</sub>**,
- (iii) and a circuit **U<sub>1</sub>** which connects the water absorption unit **W<sub>abs1</sub>** with the water desorption unit **W<sub>des1</sub>** and by means of which the aqueous liquid absorption medium **A<sub>VE</sub>** may be circulated.

The water absorption unit **W<sub>abs1</sub>** is the component in which step a) of the process according to the  
 25 invention in particular is carried out. Employable water absorption units **W<sub>abs1</sub>** include in particular the water absorbers known to those skilled in the art. Said absorbers are based on the principle of increasing the surface area of the aqueous liquid absorption medium **A<sub>VE</sub>** and simultaneously achieving the longest possible residence time of the aqueous liquid absorption medium **A<sub>VE</sub>** in the water absorber during absorption of water. It is in particular possible here to employ water  
 30 absorbers selected from the group of: packed beds, spray columns, falling-films, bubble columns, tray columns, wet scrubbers (for example Venturi scrubbers), stirred tanks and combinations of these absorbers. It is particularly preferable to employ falling-films, in particular shell and tube falling-films, as water absorbers. The water absorption unit **W<sub>abs1</sub>** may in particular also comprise an additional heat exchanger **W<sub>z1</sub>** set up such that the aqueous liquid absorption medium **A<sub>VE</sub>** is  
 35 coolable.

The water desorption unit **W<sub>des1</sub>** which comprises a heat exchanger **W<sub>x1</sub>** is the unit in which step b) of the process according to the invention in particular is carried out. The water desorption unit

$W_{des1}$  is based on the principle of supplying heat to the water-laden liquid absorption medium  $A_{VE}$  (in particular  $A_{VE1}$ ), increasing the surface area of the water-laden liquid absorption medium  $A_{VE}$  (in particular  $A_{VE1}$ ) and simultaneously achieving the longest possible residence time of the water-laden liquid absorption medium  $A_{VE}$  (in particular  $A_{VE1}$ ) in the water desorption unit.

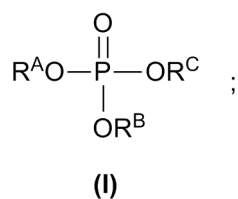
- 5 Employable water desorption units  $W_{des1}$  comprising a heat exchanger  $W_{x1}$  include in particular the combinations of heat exchanger and water desorber known to those skilled in the art, in particular horizontal tube evaporators having an upstream heat exchanger, in particular shell and tube heat exchangers, plate and frame heat exchangers. In addition the water desorption unit  $W_{des1}$  comprising a heat exchanger  $W_{x1}$  may also be a water desorber having an integrated heat
- 10 exchanger. Such water desorbers having an integrated heat exchanger are in particular climbing film evaporators, long tube vertical evaporators, short tube vertical evaporators, forced circulation evaporators, agitated thin film evaporators. It is particularly preferable to employ falling-films, in particular shell and tube falling-films, as water desorption unit  $W_{des1}$ .

- Circuit  $U_1$  in particular passes  $A_{VE1}$  from step a) of the process according to the invention from the water absorption unit  $W_{abs1}$  to the water desorption unit  $W_{des1}$  and more preferably - in particular
- 15 when the process according to the invention is carried out in continuous fashion - additionally passes  $A_{VE2}$  from step b) of the process according to the invention from the water absorption unit  $W_{des1}$  to the water desorption unit  $W_{abs1}$ .

- The circuit  $U_1$  is in particular a conduit, in particular selected from the group consisting of tube,
- 20 hose.

In a further preferred embodiment the circuit  $U_1$  also comprises a pump.

A first step of the process according to the invention comprises contacting the moist gas mixture  $G$  with an aqueous liquid absorption medium  $A_{VE}$  comprising a mixture of at least one trialkyl phosphate of structure (I) where

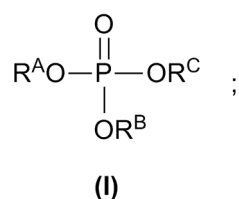


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- and at least one salt  $S$  selected from the group consisting of  $Q^+A^-$ ,  $Q^+(R^1O)_2PO_2^-$ ,  $(Q^+)_2R^2OPO_3^{2-}$ ,  $Q^+M^+R^3OPO_3^{2-}$ . The contacting may be effected in any way known to those skilled in the art, in particular in a water absorption unit  $W_{abs1}$ . The contacting causes the absorption medium  $A_{VE}$  to at least partially absorb moisture, i.e. water, from the moist gas stream  $G$  to afford an aqueous liquid
- 30 absorption medium  $A_{VE1}$  having an elevated water content compared to the aqueous liquid absorption medium  $A_{VE}$  and a gas mixture  $G_1$  having a relatively low water content compared to the moist gas mixture  $G$ .

It is preferable to cool the absorption medium **A<sub>VE</sub>** during contacting of the moist gas mixture **G** in order that as much moisture as possible is absorbed from the moist gas mixture **G**. This may be achieved, for example, via an additional heat exchanger **W<sub>z1</sub>** in the water absorption unit **W<sub>abs1</sub>**. The temperature of the absorption medium **A<sub>VE</sub>** during contacting of the moist gas mixture **G** is thus  
 5 preferably in the range from 2°C to 100°C, preferably 3°C to 80°C, more preferably 4°C to 50°C, yet more preferably 5°C to 30°C.

The absorption medium **A<sub>VE</sub>** comprises water and a mixture of at least one trialkyl phosphate of structure **(I)** where



10 and at least one salt **S** selected from the group consisting of **Q<sup>+</sup>A<sup>-</sup>**, **Q<sup>+</sup>(R<sup>1</sup>O)<sub>2</sub>PO<sub>2</sub><sup>-</sup>**, **(Q<sup>+</sup>)<sub>2</sub>R<sup>2</sup>OPO<sub>3</sub><sup>2-</sup>**, **Q<sup>+</sup>M<sup>+</sup>R<sup>3</sup>OPO<sub>3</sub><sup>2-</sup>**,

wherein **Q<sup>+</sup>** is a 1,3-dialkylimidazolium cation in which in particular the alkyl groups each independently of one another have 1 to 10 carbon atoms,

wherein **A<sup>-</sup>** is an anion selected from the group consisting of **R<sup>\*</sup>COO<sup>-</sup>**, **R<sup>'</sup>SO<sub>3</sub><sup>-</sup>**, **HSO<sub>4</sub><sup>-</sup>**, **R<sup>''</sup>SO<sub>4</sub><sup>-</sup>**,  
 15 wherein **R<sup>\*</sup>**, **R<sup>'</sup>**, **R<sup>''</sup>**, **R<sup>A</sup>**, **R<sup>B</sup>**, **R<sup>C</sup>**, **R<sup>1</sup>**, **R<sup>2</sup>**, **R<sup>3</sup>** are each independently of one another an alkyl group, in particular having 1 to 10 carbon atoms,

and wherein **M<sup>+</sup>** is an alkali metal ion, preferably **Li<sup>+</sup>**, **K<sup>+</sup>** or **Na<sup>+</sup>**, yet more preferably **K<sup>+</sup>** or **Na<sup>+</sup>**.

In a preferred embodiment of the process according to the invention the salt **S** is selected from the group consisting of **Q<sup>+</sup>A<sup>-</sup>**, **Q<sup>+</sup>(R<sup>1</sup>O)<sub>2</sub>PO<sub>2</sub><sup>-</sup>**, and **Q<sup>+</sup>** is a dialkylimidazolium cation in which the alkyl  
 20 groups each independently of one another have 1 to 6, preferably 1 or 4, more preferably 1 or 2 carbon atoms, and **A<sup>-</sup>** is an anion selected from the group consisting of **R<sup>\*</sup>COO<sup>-</sup>**, **R<sup>'</sup>SO<sub>3</sub><sup>-</sup>**, **R<sup>''</sup>SO<sub>4</sub><sup>-</sup>**, wherein **R<sup>\*</sup>**, **R<sup>1</sup>**, **R<sup>'</sup>**, **R<sup>''</sup>**, **R<sup>A</sup>**, **R<sup>B</sup>**, **R<sup>C</sup>** are each independently of one another an alkyl group having 1 to 6, preferably 1 to 4, more preferably 1 or 2, carbon atoms.

In a more preferred embodiment of the process according to the invention, the salt **S** has the  
 25 general formula **Q<sup>+</sup>(R<sup>1</sup>O)<sub>2</sub>PO<sub>2</sub><sup>-</sup>**, and **Q<sup>+</sup>** is a dialkylimidazolium cation in which the alkyl groups are each independently of one another methyl or ethyl, and **R<sup>1</sup>**, **R<sup>A</sup>**, **R<sup>B</sup>**, **R<sup>C</sup>** are each independently of one another methyl or ethyl.

In a yet more preferred embodiment of the process according to the invention, the salt **S** has the  
 general formula **Q<sup>+</sup>(R<sup>1</sup>O)<sub>2</sub>PO<sub>2</sub><sup>-</sup>**, and **Q<sup>+</sup>** is selected from the group consisting of 1,3-  
 30 dimethylimidazolium, 1,3-diethylimidazolium, 1-ethyl-3-methylimidazolium; **R<sup>A</sup>**, **R<sup>B</sup>**, **R<sup>C</sup>**, **R<sup>1</sup>** is methyl or ethyl.

It is moreover particularly preferable in all of the aforementioned embodiments of the process according to the invention when  $R^A$ ,  $R^B$ ,  $R^C$  are independently of one another selected from methyl, ethyl; yet more preferably  $R^A = R^B = R^C = \text{methyl}$  or  $R^A = R^B = R^C = \text{ethyl}$ ; particularly preferably  $R^A = R^B = R^C = \text{ethyl}$ .

- 5 This is because it has been found that, surprisingly, imidazolium salts having at least one ethyl group have a particularly small contact angle and thus ensure particularly good surface wetting. This results in a relatively large contact area, thus also in fewer nonwetted spaces and thus in improved heat transfer inside the apparatus  $V_1$  and thus also in a particularly efficient process.

10 The liquid absorption medium  $A_{VE}$  is aqueous, i.e. it comprises water and is thus an aqueous solution.

In particular, in the aqueous liquid absorption medium  $A_{VE}$  the total weight of all trialkyl phosphates of structure (I) and all salts  $S$  is in the range from 65 wt% to 95 wt% based on the total weight of the aqueous solution. Yet more preferably the total weight of all trialkyl phosphates of structure (I) and all salts  $S$  in  $A_{VE}$  is in the range from 70 wt% to 90 wt% based on the total weight of the aqueous solution, yet more preferably in the range from 75 wt% to 87 wt%.

15 In the process according to the invention the ratio of all trialkyl phosphates of structure (I) to the salts  $S$  in the absorption medium  $A_{VE}$  is not further restricted. However, it is preferable to employ in the process according to the invention an absorption medium  $A_{VE}$  in which the ratio of the total weight of all trialkyl phosphates of structure (I) to the total weight of all salts  $S$  is in the range 1 : 9999 to 1 : 9, more preferably 1 : 9999 to 1 : 99, yet more preferably 1 : 9999 to 1 : 999.

The gas mixture  $G_1$  obtained in the first step of the process according to the invention and having a relatively low water content compared to the moist gas mixture  $G$  then represents the dehumidified gas stream which, depending on the application, can be returned to living or working spaces in the form of dehumidified air or in the case of natural gas can be supplied to power generation.

25 The aqueous liquid absorption medium  $A_{VE1}$  obtained in the first step of the process according to the invention has an elevated water content compared to the aqueous liquid absorption medium  $A_{VE}$ . It will be appreciated that in terms of the trialkyl phosphates of structure (I) comprised by it and the salts  $S$  comprised by it,  $A_{VE1}$  is identical to  $A_{VE}$  and is preferably distinguished therefrom only by its water content.

30 The second step of the process according to the invention then comprises partially removing water from the aqueous liquid absorption medium  $A_{VE1}$  to obtain an aqueous liquid absorption medium  $A_{VE2}$  having a relatively low water content compared to the aqueous liquid absorption medium  $A_{VE1}$ .

This in particular comprises additionally supplying heat to the aqueous liquid absorption medium  $A_{VE1}$ . The supply of heat and the at least partial removal may be effected in any way known to those skilled in the art, in particular in a water desorption unit  $W_{des1}$  comprising a heat exchanger  $W_{x1}$ . The partial removal of water from the aqueous liquid absorption medium  $A_{VE1}$  affords an

aqueous liquid absorption medium **A<sub>VE2</sub>** having a relatively low water content compared to the aqueous liquid absorption medium **A<sub>VE1</sub>**.

It will be appreciated that in terms of the trialkyl phosphates of structure **(I)** comprised by it and the salts **S** comprised by it the aqueous liquid absorption medium **A<sub>VE2</sub>** is identical to **A<sub>VE1</sub>** and is preferably distinguished therefrom only by its water content.

It is an essential feature of the process according to the invention that the apparatus **V<sub>1</sub>** at least partially comprises a surface made of a steel material of construction **O<sub>st</sub>** (in the context of the invention **O<sub>st</sub>** is short for "surface made of a steel material of construction").

A "steel material of construction" in the context of the present invention is to be understood as meaning in particular any iron alloy where the mass fraction of iron is greater than the mass fraction of every other element present. The proportion of iron in the steel material of construction is preferably > 50 wt%, more preferably  $\geq 60$  wt%, yet more preferably  $\geq 70$  wt%, yet more preferably  $\geq 80$  wt%, yet more preferably  $\geq 99$  wt%.

In accordance with the invention in addition to iron the steel material of construction comprises in particular at least one alloying metal selected from the group consisting of nickel, chromium, vanadium, molybdenum, niobium, tungsten, cobalt, magnesium, manganese, silicon, zinc, lead, copper, titanium, more preferably selected from the group consisting of nickel, chromium, vanadium, molybdenum, niobium, tungsten, cobalt, magnesium, manganese, titanium, particularly chromium, wherein this yet more preferably has a mass fraction in the steel material of construction greater than 10.5 wt% but smaller than 50 wt%.

It is yet more preferable when at the same time the carbon content in the steel material of construction is then always < 2.06 wt%, yet more preferably  $\leq 1.2$  wt%.

It will be appreciated that the sum of the contents of iron, alloying metal (for example chromium) and carbon in the steel material of construction must not exceed 100 wt%.

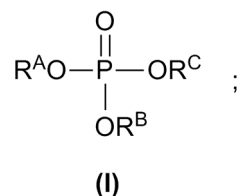
The steel material of construction may in particular be in the form of a wrought alloy or of a cast alloy.

It is a further essential feature of the process according to the invention that in the apparatus **V<sub>1</sub>** at least one of the aqueous liquid absorption media selected from the group consisting of **A<sub>VE</sub>**, **A<sub>VE1</sub>**, **A<sub>VE2</sub>** contacts the surface made of a steel material of construction **O<sub>st</sub>** via at least one contact surface. This means that the particular aqueous liquid absorption medium **A<sub>VE</sub>**, **A<sub>VE1</sub>** or **A<sub>VE2</sub>** is in direct contact with the surface made of a steel material of construction **O<sub>st</sub>** at this contact surface. In the context of the present invention "in direct contact" is to be understood as meaning in particular "wetting". It will be appreciated that the aqueous liquid absorption medium selected from the group consisting of **A<sub>VE</sub>**, **A<sub>VE1</sub>**, **A<sub>VE2</sub>** and the steel material of construction comprised in the contact surface are thus in direct contact. This is because it has been found that, surprisingly, the contact angle of the absorption media according to the invention are particularly small and thus ensure particularly good heat transfer in the case where said media are aqueous.

In the embodiment according to the invention in which an apparatus  $V_1$  is employed and comprises the following components:

- (i) at least one water absorption unit  $W_{abs1}$  set up for contacting the moist gas mixture with the aqueous liquid absorption medium  $A_{VE}$ ,
  - 5 (ii) at least one water desorption unit  $W_{des1}$  which comprises a heat exchanger  $W_{x1}$  and is set up for at least partially removing water from an aqueous liquid absorption medium  $A_{VE}$ ,
  - (iii) and a circuit  $U_1$  which connects the water absorption unit  $W_{abs1}$  with the water desorption unit  $W_{des1}$  and by means of which the aqueous liquid absorption medium  $A_{VE}$  may be circulated,
- 10 the contact surface at which the aqueous liquid absorption medium selected from the group consisting of  $A_{VE}$ ,  $A_{VE1}$ ,  $A_{VE2}$  contacts the surface made of a steel material of construction  $O_{st}$  is disposed in particular in at least one of the components selected from the group water absorption unit  $W_{abs1}$ , water desorption unit  $W_{des1}$ , circuit  $U_1$ , preferably in at least one of the components selected from the group water absorption unit  $W_{abs1}$ , water desorption unit  $W_{des1}$ .
- 15 This is because it has been found that, surprisingly, the mixtures of at least one trialkyl phosphate of structure (I) and at least one salt  $S$  according to the invention show particularly good wetting of steel materials of construction, thus ensure particularly good heat transfer and are thus particularly suitable as absorption media in the apparatus  $V_1$  having a surface made of a steel material of construction  $O_{st}$  in which one of the aqueous liquid absorption media selected from the group
- 20 consisting of  $A_{VE}$ ,  $A_{VE1}$ ,  $A_{VE2}$  is in direct contact with the surface made of a steel material of construction  $O_{st}$ .
- In a further preferred embodiment the process according to the invention is carried out in continuous fashion. This is to be understood as meaning in particular that following step b) the steps a) and b) are performed at least one more time and that the aqueous liquid absorption
- 25 medium  $A_{VE}$  employed in the steps a) additionally performed in each case is at least partially the aqueous liquid absorption medium  $A_{VE2}$  obtained from the step b) performed immediately beforehand, i.e. in particular the water content of the aqueous liquid absorption medium  $A_{VE}$  employed in the step a) additionally performed in each case and of the aqueous liquid absorption medium  $A_{VE2}$  from the immediately preceding step b) is identical.
- 30 It is yet more preferable when this embodiment comprises heating aqueous liquid absorption medium  $A_{VE1}$  with heat from aqueous liquid absorption medium  $A_{VE2}$ . This may be carried out in an additional heat exchanger  $W_{y1}$ , in particular selected from the group consisting of shell and tube heat exchangers and plate and frame heat exchangers. This makes it possible to carry out the process according to the invention in a particularly energy efficient fashion.
- 35 The invention also relates in a further aspect to an apparatus  $V_2$  for dehumidifying a moist gas mixture, in particular moist air, comprising the components

- (i) an aqueous liquid absorption medium **A<sub>VO</sub>** which comprises a mixture of at least one trialkyl phosphate of structure **(I)** where



and at least one salt **S** selected from the group consisting of  $\text{Q}^+\text{A}^-$ ,  $\text{Q}^+(\text{R}^1\text{O})_2\text{PO}_2^-$ ,  
 5  $(\text{Q}^+)_2\text{R}^2\text{OPO}_3^{2-}$ ,  $\text{Q}^+\text{M}^+\text{R}^3\text{OPO}_3^{2-}$ ,

- (ii) at least one water absorption unit **W<sub>abs2</sub>** set up for contacting the moist gas mixture with the aqueous liquid absorption medium **A<sub>VO</sub>**,  
 (iii) at least one water desorption unit **W<sub>des2</sub>** which comprises a heat exchanger **W<sub>x2</sub>** and is set up for at least partially removing water from an aqueous liquid absorption medium **A<sub>VO</sub>**,  
 10 (iv) and a circuit **U<sub>2</sub>** which connects the water absorption unit **W<sub>abs2</sub>** with the water desorption unit **W<sub>des2</sub>** and by means of which the aqueous liquid absorption medium **A<sub>VO</sub>** may be circulated,

wherein at least one of the components water absorption unit **W<sub>abs2</sub>**, water desorption unit **W<sub>des2</sub>**, circuit **U<sub>2</sub>** at least partially comprises a surface made of a steel material of construction **O<sub>st</sub>**, and  
 15 **O<sub>st</sub>**, and

wherein disposed in the apparatus **V<sub>2</sub>** is at least one contact surface at which the aqueous liquid absorption medium **A<sub>VO</sub>** contacts the surface made of a steel material of construction **O<sub>st</sub>**, characterized in that

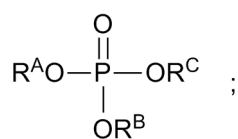
**Q<sup>+</sup>** is a dialkylimidazolium cation in which in particular the alkyl groups each independently of one another have 1 to 10 carbon atoms,  
 20

wherein **A<sup>-</sup>** is an anion selected from the group consisting of  $\text{R}^*\text{COO}^-$ ,  $\text{R}'\text{SO}_3^-$ ,  $\text{HSO}_4^-$ ,  $\text{R}''\text{SO}_4^-$ , wherein **R<sup>\*</sup>**, **R'**, **R''**, **R<sup>A</sup>**, **R<sup>B</sup>**, **R<sup>C</sup>**, **R<sup>1</sup>**, **R<sup>2</sup>**, **R<sup>3</sup>** are each independently of one another an alkyl group, in particular having 1 to 10, preferably 1 to 8, more preferably 1 to 6, yet more preferably 1 to 4, still more preferably 1 to 2, carbon atoms

25 and wherein **M<sup>+</sup>** is an alkali metal ion, preferably  $\text{Li}^+$ ,  $\text{K}^+$  or  $\text{Na}^+$ , yet more preferably  $\text{K}^+$  or  $\text{Na}^+$ .

The apparatus **V<sub>2</sub>** according to the invention is suitable for dehumidifying a moist gas mixture, in particular moist air. Said apparatus comprises the following components:

As the first component, the apparatus **V<sub>2</sub>** according to the invention comprises an aqueous liquid absorption medium **A<sub>VO</sub>**, which comprises a mixture of at least one trialkyl phosphate of structure **(I)**  
 30 where



(I)

and at least one salt **S** selected from the group consisting of  $\text{Q}^+\text{A}^-$ ,  $\text{Q}^+(\text{R}^1\text{O})_2\text{PO}_2^-$ ,  $(\text{Q}^+)_2\text{R}^2\text{OPO}_3^{2-}$ ,  $\text{Q}^+\text{M}^+\text{R}^3\text{OPO}_3^{2-}$ , wherein  $\text{Q}^+$  is a dialkylimidazolium cation in which in particular the alkyl groups each independently of one another have 1 to 10 carbon atoms,

- 5 wherein  $\text{A}^-$  is an anion selected from the group consisting of  $\text{R}^*\text{COO}^-$ ,  $\text{R}'\text{SO}_3^-$ ,  $\text{HSO}_4^-$ ,  $\text{R}''\text{SO}_4^-$ , wherein  $\text{R}^*$ ,  $\text{R}'$ ,  $\text{R}''$ ,  $\text{R}^{\text{A}}$ ,  $\text{R}^{\text{B}}$ ,  $\text{R}^{\text{C}}$ ,  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$  are each independently of one another an alkyl group, in particular having 1 to 10 carbon atoms,

and wherein  $\text{M}^+$  is an alkali metal ion, preferably  $\text{Li}^+$ ,  $\text{K}^+$  or  $\text{Na}^+$ , yet more preferably  $\text{K}^+$  or  $\text{Na}^+$ .

- In a preferred embodiment of the apparatus **V**<sub>2</sub> according to the invention in the absorption medium
- 10 **A**<sub>VO</sub> the salt **S** is selected from the group consisting of  $\text{Q}^+\text{A}^-$ ,  $\text{Q}^+(\text{R}^1\text{O})_2\text{PO}_2^-$ , and  $\text{Q}^+$  is a dialkylimidazolium cation in which the alkyl groups each independently of one another have 1 to 6, preferably 1 or 4, more preferably 1 or 2 carbon atoms, and  $\text{A}^-$  is an anion selected from the group consisting of  $\text{R}^*\text{COO}^-$ ,  $\text{R}'\text{SO}_3^-$ ,  $\text{R}''\text{SO}_4^-$ , wherein  $\text{R}^*$ ,  $\text{R}'$ ,  $\text{R}''$ ,  $\text{R}^{\text{A}}$ ,  $\text{R}^{\text{B}}$ ,  $\text{R}^{\text{C}}$  are each independently of one another an alkyl group having 1 to 6, preferably 1 to 4, more preferably 1 or 2, carbon atoms.
- 15 In a more preferred embodiment of the apparatus **V**<sub>2</sub> according to the invention in the absorption medium **A**<sub>VO</sub> the salt **S** has the general formula  $\text{Q}^+(\text{R}^1\text{O})_2\text{PO}_2^-$ , and  $\text{Q}^+$  is a dialkylimidazolium cation in which the alkyl groups are each independently of one another methyl or ethyl, and  $\text{R}^1$ ,  $\text{R}^{\text{A}}$ ,  $\text{R}^{\text{B}}$ ,  $\text{R}^{\text{C}}$  are each independently of one another methyl or ethyl.

- In a yet more preferred embodiment of the apparatus **V**<sub>2</sub> according to the invention in the
- 20 absorption medium **A**<sub>VO</sub> the salt **S** has the general formula  $\text{Q}^+(\text{R}^1\text{O})_2\text{PO}_2^-$ , and  $\text{Q}^+$  is selected from the group consisting of 1,3-dimethylimidazolium, 1,3-diethylimidazolium, 1-ethyl-3-methylimidazolium;  $\text{R}^{\text{A}}$ ,  $\text{R}^{\text{B}}$ ,  $\text{R}^{\text{C}}$ ,  $\text{R}^1$  is methyl or ethyl.

- It is moreover particularly preferable in all of the aforementioned embodiments of the apparatus **V**<sub>2</sub> according to the invention when in the absorption medium **A**<sub>VO</sub>  $\text{R}^{\text{A}}$ ,  $\text{R}^{\text{B}}$ ,  $\text{R}^{\text{C}}$  are independently of one
- 25 another selected from methyl, ethyl; yet more preferably  $\text{R}^{\text{A}} = \text{R}^{\text{B}} = \text{R}^{\text{C}} = \text{methyl}$  or  $\text{R}^{\text{A}} = \text{R}^{\text{B}} = \text{R}^{\text{C}} = \text{ethyl}$ ; particularly preferably  $\text{R}^{\text{A}} = \text{R}^{\text{B}} = \text{R}^{\text{C}} = \text{ethyl}$ .

- This is because it has been found that, surprisingly, imidazolium salts where  $\text{R} = \text{ethyl}$  group have a particularly small contact angle and thus ensure particularly good surface wetting. This results in a relatively large contact area, thus also in fewer nonwetted spaces and thus in improved heat
- 30 transfer inside the apparatus **V**<sub>2</sub>.

The liquid absorption medium **A**<sub>VO</sub> is aqueous, i.e. it comprises water and is thus an aqueous solution.

In particular, in the apparatus **V<sub>2</sub>** according to the invention in the aqueous liquid absorption medium **A<sub>VO</sub>** the total weight of all trialkyl phosphates of structure **(I)** and all salts **S** is in the range from 65 wt% to 95 wt% based on the total weight of the aqueous solution. Yet more preferably the total weight of all trialkyl phosphates of structure **(I)** and all salts **S** in **A<sub>VO</sub>** is in the range 70 wt% to 90 wt% based on the total weight of the aqueous solution, yet more preferably in the range 75 wt% to 87 wt%.

In the apparatus **V<sub>2</sub>** according to the invention the ratio of all trialkyl phosphates of structure **(I)** to the salts **S** in the absorption medium **A<sub>VO</sub>** is not further restricted. However, it is preferable to employ in the apparatus **V<sub>2</sub>** according to the invention an absorption medium **A<sub>VO</sub>** in which the ratio of the total weight of all trialkyl phosphates of structure **(I)** to the total weight of all salts **S** is in the range 1 : 9999 to 1 : 9, more preferably 1 : 9999 to 1 : 99, yet more preferably 1 : 9999 to 1 : 999.

As a second component the apparatus **V<sub>2</sub>** according to the invention comprises a water absorption unit **W<sub>abs2</sub>** set up for contacting the moist gas mixture with the aqueous liquid absorption medium **A<sub>VO</sub>**. The water absorption unit **W<sub>abs2</sub>** may in particular comprise an additional heat exchanger **W<sub>z2</sub>** set up such that the aqueous liquid absorption medium **A<sub>VO</sub>** is coolable. Employable water absorption units **W<sub>abs2</sub>** of this kind include in particular the water absorbers known to those skilled in the art. Said absorbers are based on the principle of increasing the surface area of the aqueous liquid absorption medium **A<sub>VO</sub>** and simultaneously achieving the longest possible residence time of the aqueous liquid absorption medium **A<sub>VO</sub>** in the water absorber during absorption of water. It is in particular possible here to employ water absorbers selected from the group of: packed beds, spray columns, falling-films, bubble columns, tray columns, wet scrubbers (for example Venturi scrubbers), stirred tanks and combinations of these absorbers. It is particularly preferable to employ falling-films, in particular shell and tube falling-films, as water absorbers.

As a third component the apparatus **V<sub>2</sub>** according to the invention comprises a water desorption unit **W<sub>des2</sub>** which comprises a heat exchanger **W<sub>x2</sub>** and is set up for at least partially removing water from the aqueous liquid absorption medium **A<sub>VO</sub>**. Particularly the combinations of heat exchanger and water desorber known to those skilled in the art may be employed therefor. The water desorption unit **W<sub>des2</sub>** is based on the principle of supplying heat to the aqueous liquid absorption medium **A<sub>VO</sub>**, increasing the surface area of the aqueous liquid absorption medium **A<sub>VO</sub>** and simultaneously achieving the longest possible residence time of the aqueous liquid absorption medium **A<sub>VO</sub>** in the water desorption unit.

Employable water desorption units **W<sub>des2</sub>** comprising a heat exchanger **W<sub>x2</sub>** include in particular the combinations of heat exchanger and water desorber known to those skilled in the art, in particular horizontal tube evaporators having an upstream heat exchanger, in particular shell and tube heat exchangers, plate and frame heat exchangers. In addition the water desorption unit **W<sub>des2</sub>** comprising a heat exchanger **W<sub>x2</sub>** may also be a water desorber having an integrated heat exchanger. Such water desorbers having an integrated heat exchanger are in particular climbing film evaporators, long tube vertical evaporators, short tube vertical evaporators, forced circulation

evaporators, agitated thin film evaporators. It is particularly preferable to employ as water desorption unit  $\mathbf{W}_{des2}$  falling-films, in particular shell and tube falling-films.

As a fourth component the apparatus  $\mathbf{V}_2$  according to the invention comprises a circuit  $\mathbf{U}_2$  which connects the water absorption unit  $\mathbf{W}_{abs2}$  with the water desorption unit  $\mathbf{W}_{des2}$  and by means of  
 5 which the aqueous liquid absorption medium  $\mathbf{A}_{vo}$  may be circulated. The circuit  $\mathbf{U}_2$  is preferably a conduit, yet more preferably selected from the group consisting of tube, hose. In a further preferred embodiment the circuit  $\mathbf{U}_2$  also comprises a pump.

It is an essential feature of the apparatus  $\mathbf{V}_2$  according to the invention that said apparatus at least partially comprises a surface made of a steel material of construction  $\mathbf{O}_{st}$  (in the context of the  
 10 invention  $\mathbf{O}_{st}$  is short for "surface made of a steel material of construction").

It is a further essential feature of the apparatus  $\mathbf{V}_2$  according to the invention that disposed in said apparatus is a contact surface at which the aqueous liquid absorption medium  $\mathbf{A}_{vo}$  contacts the surface made of a steel material of construction  $\mathbf{O}_{st}$ . This is to be understood as meaning that at this contact surface the aqueous liquid absorption medium  $\mathbf{A}_{vo}$  is in direct contact with the surface  
 15 made of a steel material of construction  $\mathbf{O}_{st}$ . In the context of the present invention "in direct contact" is to be understood as meaning in particular "wetting". It will be appreciated that the aqueous liquid absorption medium  $\mathbf{A}_{vo}$  and the steel material of construction comprised in the contact surface are thus in direct contact.

In a preferred embodiment the apparatus  $\mathbf{V}_2$  comprises a further heat exchanger  $\mathbf{W}_{y2}$  (additional to the heat exchanger  $\mathbf{W}_{x2}$  comprised in the water desorption unit  $\mathbf{W}_{des2}$ ). The heat exchanger  $\mathbf{W}_{y2}$  is set up such that aqueous liquid absorption medium  $\mathbf{A}_{vo}$  sent from the water absorption unit  $\mathbf{W}_{abs2}$  to the water desorption unit  $\mathbf{W}_{des2}$  is suppleable with heat from aqueous liquid absorption medium  $\mathbf{A}_{vo}$ , said medium being conducted away from the water desorption unit  $\mathbf{W}_{des2}$ . This can be ensured in particular by employing as heat exchanger  $\mathbf{W}_{y2}$  in particular a heat exchanger selected  
 20 from shell and tube heat exchangers, plate and frame heat exchangers.  
 25

In a further preferred embodiment the apparatus  $\mathbf{V}_2$  is part of an absorption heat pump. This absorption heat pump then comprises as further components a condenser, an evaporator and a coolant, wherein the coolant is water.

The condenser is in particular connected to the water desorption unit  $\mathbf{W}_{des2}$  via a conduit and is set up for condensing water at least partially removed from the aqueous liquid absorption medium  $\mathbf{A}_{vo}$  in the water desorption unit  $\mathbf{W}_{des2}$ . The condenser preferably also comprises a cooling water circuit.  
 30

The evaporator is in particular connected to the condenser via a conduit (which may comprise a throttling means) and connected to the water absorption unit  $\mathbf{W}_{abs2}$  via a further conduit and is set up for evaporating condensed water from the condenser. The evaporator preferably also comprises  
 35 a pressure of  $< 1$  bar, more preferably  $< 0.1$  bar, to permit evaporation of the condensed water at the lowest possible temperatures. The evaporator may further preferably additionally comprise an

apparatus from which heat may be drawn and so that the condensed water may be evaporated (for example a coolant conduit in which coolant is passed into the space in which water is evaporated).

The Figures 1 and 2 elucidated hereinbelow show preferred embodiments of the process according to the invention and the apparatus according to the invention.

- 5 Figure 1 (abbreviated to "Fig. 1") shows an embodiment of the apparatus  $V_2/V_1$  according to the invention.

The apparatus  $V_2$  shown in Figure 1 comprises a water absorption unit  $W_{abs2}$  <103> (with optional additional heat exchanger  $W_{z2}$  <104>) to which a conduit <101> leads and from which a conduit <102> leads away, a water desorption unit  $W_{des2}$  which comprises a heat exchanger  $W_{x2}$  <108>  
 10 and a water desorber <109> and to which conduit <111> leads and from which conduits <110>, <112> and <113> lead away, and a circuit  $U_2$  formed from conduits <106>, <111> and <113> or <106>, <111>, <112> and <105> (in each case optionally with conduit <114>). The apparatus in Figure 1 may also optionally comprise a further heat exchanger  $W_{y2}$  <107> to which conduits <106> and <112> lead and from which conduits <105> and <111> lead away. In addition the  
 15 apparatus  $V_2$  also comprises an aqueous liquid absorption medium  $A_{vo}$ . Said medium is disposed in one or more of the abovementioned components water absorption unit  $W_{abs2}$ , water desorption unit  $W_{des2}$ , circuit  $U_2$ . Water absorption unit  $W_{abs2}$  <103> may optionally also comprise an additional heat exchanger  $W_{z2}$  <104>. Apparatus  $V_2$ , in particular at least one of the components selected from the group consisting of water absorption unit  $W_{abs2}$ , water desorption unit  $W_{des2}$ , circuit  $U_2$ , at  
 20 least partially comprises a surface made of a steel material of construction  $O_{st}$  and there is at least one contact surface at which the aqueous liquid absorption medium  $A_{vo}$  contacts the surface made of a steel material of construction  $O_{st}$ . Optionally, circuit  $U_2$  may also additionally comprise a pump for conveying the aqueous liquid absorption medium.

Apparatus  $V_1$  corresponds to apparatus  $V_2$  without absorption medium  $A_{vo}$ , wherein in the figure  
 25 description for Figure 1 and Figure 2 the terms  $U_2$ ,  $W_{abs2}$ ,  $W_{des2}$ ,  $W_{x2}$ ,  $W_{y2}$ ,  $W_{z2}$  are to be replaced by  $U_1$ ,  $W_{abs1}$ ,  $W_{des1}$ ,  $W_{x1}$ ,  $W_{y1}$  and  $W_{z1}$  respectively.

The process according to the invention will now be illustratively described with reference to apparatus  $V_1$  using Figure 1:

A stream of moist gas mixture  $G$  (said stream may for example be moist air, moist natural gas or  
 30 moist gas mixture originating from the evaporator of an absorption chiller - see also Figure 2 with regard to this option) is supplied via conduit <101> to a water absorption unit  $W_{abs1}$  <103> and contacted there with the aqueous liquid absorption medium  $A_{ve}$  supplied to the water absorption unit  $W_{abs1}$  <103> via the conduit <105> or via the conduit <113>. The water absorption unit  $W_{abs1}$  <103> may be any of the water absorbers recited hereinabove for  $W_{abs1}$ , in particular a falling-film.  
 35 Contacting, in the water absorption unit  $W_{abs1}$  <103>, gas mixture  $G$  supplied via conduit <101> with the aqueous liquid absorption medium  $A_{ve}$  supplied via the conduit <105> or via the conduit <113> affords an aqueous liquid absorption medium  $A_{ve1}$  having an elevated water content

compared to the aqueous liquid absorption medium  $A_{VE}$  and a stream of a gas mixture  $G_1$  discharged via the conduit <102>,  $G_1$  having a relatively low water content compared to the moist gas mixture  $G$ . Depending on the application  $G_1$  is in particular dehumidified air or dehumidified natural gas. The water absorption unit  $W_{abs1}$  <103> may optionally also comprise an additional heat exchanger  $W_{z1}$  <104>. Preferably via the conduits <106>, <111> and the heat exchanger  $W_{y1}$  <107> (or, when heat exchanger  $W_{y1}$  <107> is not employed, via conduits <106>, <111> and <114>) the aqueous liquid absorption medium  $A_{VE1}$  is then passed to the water desorption unit  $W_{des1}$  composed of the heat exchanger  $W_{x1}$  <108> and the water desorber <109>. The water-laden liquid absorption medium  $A_{VE1}$  may additionally be supplied with heat in the optional heat exchanger  $W_{y1}$  <107>. The at least partial removal of water from aqueous liquid absorption medium  $A_{VE1}$  is then carried out in the water desorber <109> to afford an aqueous liquid absorption medium  $A_{VE2}$  having a relatively low water content compared to the aqueous liquid absorption medium  $A_{VE1}$ . The water removed is then discharged from the water desorber <109> as liquid or vapour, preferably as vapour, via a conduit <110>. The aqueous liquid absorption medium  $A_{VE2}$  is then discharged from the water desorber <109> and returned to the water absorption unit  $W_{abs1}$  <103>. This may either be carried out directly, i.e. via the conduit <113> which is shown in dashed form in Figure 1. Alternatively and preferably the aqueous liquid absorption medium  $A_{VE2}$  may also be supplied via the conduit <112> to the optional heat exchanger  $W_{y1}$  <107> in which the aqueous liquid absorption medium  $A_{VE1}$  supplied via conduit <106> to the optional heat exchanger  $W_{y1}$  <107> is then supplied with heat from the aqueous liquid absorption medium  $A_{VE2}$  supplied via conduit <112> to the optional heat exchanger  $W_{y1}$  <107>. Once the concentrated aqueous liquid absorption medium  $A_{VE2}$  has been supplied to the water absorption unit  $W_{abs1}$  via conduit <105> or <113> said medium is reused as  $A_{VE}$  for at least partially dehumidifying the gas stream in a new cycle. It is essential to the invention that in this process the apparatus according to Figure 1, preferably at least one of the components selected from the group consisting of water absorption unit  $W_{abs1}$  <103> (in Figure 1 said unit comprises the heat exchanger <104>), water desorption unit  $W_{des1}$  (in Figure 1 said unit comprises the heat exchanger <108>), circuit  $U_1$  (composed in Figure 1 of the conduits <106>, <111>, <113>, or <106>, <111>, <112>, <105>, and in each case optionally also conduit <114>) at least partially comprises a surface made of a steel material of construction  $O_{st}$  and that disposed in the apparatus is at least one contact surface at which at least one of the aqueous liquid absorption media  $A_{VE1}$ ,  $A_{VE}$ ,  $A_{VE2}$  contacts the surface made of a steel material of construction  $O_{st}$ .

Figure 2 (abbreviated as "Fig. 2") shows in schematic fashion an absorption chiller into which an apparatus  $V_2$  is integrated. The constituents <101> to <114> are shown as for the apparatus  $V_2$  described in Figure 1. Additionally, the absorption chiller in Figure 2 also comprises a condenser <211> which is connected to the water desorption unit  $W_{des2}$  <109> via the conduit <110> and is set up for condensing water at least partially removed from the aqueous liquid absorption medium  $A_{vo}$  in the water desorption unit  $W_{des2}$ . Condenser <211> preferably also comprises a heat exchanger <212> with which cooling water may be supplied.

The absorption chiller shown in Figure 2 also comprises an evaporator <214> connected to the condenser <211> via a conduit <216> (which may optionally comprise a throttling means <213>) and connected via the conduit <101> with the water absorption unit  $\mathbf{W}_{abs2}$ . The evaporator <214> is set up to evaporate condensed water from the condenser. Additionally, the evaporator <214> can  
 5 further preferably also comprise a heat exchanger <215> which supplies a medium, heat being drawn off from the medium to thus evaporate the condensed water (for example a coolant conduit with, in particular, water as coolant, this coolant being passed into the evaporator <214>).

In an embodiment of the process according to the invention (described hereinbelow with reference to apparatus  $\mathbf{V}_1$  using Figure 2) moist gas mixture  $\mathbf{G}$  originating from evaporator <214> is passed  
 10 via the conduit <101> to the water absorption unit  $\mathbf{W}_{abs1}$  <103>. The water removed in water desorption unit  $\mathbf{W}_{des1}$  is supplied via the conduit <110> to the condenser <211> in which said water is recondensed. A cooling water circuit as heat exchanger <212> installed in the condenser is optionally likewise used therefor. The condensed water is then supplied via a conduit <216> to the evaporator <214> in which the evaporation of water is effected in particular at low pressures, thus  
 15 bringing about a cooling effect. This may optionally also be effected using a throttling means <213>. This achieves a cooling action in the evaporator <214> and, for example, coolant may be cooled via the heat exchanger <215>. The water vapour generated is then returned to the water absorption unit  $\mathbf{W}_{abs1}$  <103> via conduit <101>.

The examples which follow are intended to elucidate the present invention without limiting said  
 20 invention in any way.

## Examples

Inventive examples **I1** to **I3** and comparative example **C1** were carried out.

### 1. Chemicals used

5

EMIM DEP (= ethylmethylimidazolium diethyl phosphate) was obtained from Iolitec.

TEP (= triethyl phosphate) was obtained from Sigma Aldrich.

### 2. Experimental procedure

10

3 drops of the respective solution were dropped onto a steel plate (steel, purity > 99.0%) having dimensions of 3 cm x 7 cm and a maximum thickness of 3 mm. The contact angle determination was carried out according to SOP 1827. The results are shown in the table which follows.

**C1** is the comparative test with a mixture of EMIM DEP and 10 wt% of water, while in the examples **I1**, **I2** and **I3** mixtures of EMIM DEP, 10 wt% of water and 10 wt%, 1 wt% and 0.1 wt% of TEP respectively (the wt% values are always based on the total weight of the mixture) were analyzed.

### 3. Results

| Experiment | solution employed                                       | Contact angle (°) |
|------------|---------------------------------------------------------|-------------------|
| <b>C1</b>  | 90 wt% of EMIM DEP + 10 wt% of water                    | 52.9              |
| <b>I1</b>  | 80 wt% of EMIM DEP + 10 wt% of water + 10 wt% of TEP    | 36                |
| <b>I2</b>  | 89 wt% of EMIM DEP + 10 wt% of water + 1 wt% of TEP     | 37.2              |
| <b>I3</b>  | 89.9 wt% of EMIM DEP + 10 wt% of water + 0.1 wt% of TEP | 47.5              |

20 The results show that the inventive absorption media (**I1** – **I3**), which comprise a trialkyl phosphate (in this case triethyl phosphate), exhibit a small contact angle to the steel-containing surface compared to those of the prior art (**C1**). This results in improved surface wetting and thus in greater and more efficient heat exchange in the process according to the invention and the apparatus according to the invention.

## Claims

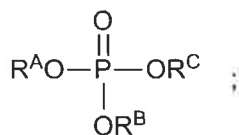
1. Process for dehumidifying a moist gas mixture **G**, in particular moist air, in an apparatus **V**<sub>1</sub>, comprising the steps of:
  - 5 (a) contacting the moist gas mixture **G** with an aqueous liquid absorption medium **A**<sub>VE</sub> comprising a mixture of at least one trialkyl phosphate of structure (I) where
 
$$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}^{\text{A}}\text{O}-\text{P}-\text{OR}^{\text{C}} \\ | \\ \text{OR}^{\text{B}} \end{array} ;$$
 (I)
 

and at least one salt **S** selected from the group consisting of  $\text{Q}^+(\text{R}^1\text{O})_2\text{PO}_2^-$ , wherein **A**<sub>VE</sub> at least partially absorbs water from the moist gas mixture **G**,
  - 10 to afford an aqueous liquid absorption medium **A**<sub>VE1</sub> having an elevated water content compared to **A**<sub>VE</sub> and a gas mixture **G**<sub>1</sub> having a relatively low water content compared to the moist gas mixture **G**,
  - (b) partially removing water from **A**<sub>VE1</sub> to obtain an aqueous liquid absorption medium **A**<sub>VE2</sub> having a relatively low water content compared to **A**<sub>VE1</sub>,
  - 15 wherein the apparatus **V**<sub>1</sub> at least partially comprises a surface made of a steel material of construction **O**<sub>st</sub> and in the apparatus **V**<sub>1</sub> at least one of **A**<sub>VE</sub>, **A**<sub>VE1</sub>, **A**<sub>VE2</sub> contacts the surface made of a steel material of construction **O**<sub>st</sub> via at least one contact surface, wherein
 

**Q**<sup>+</sup> is 1-ethyl-3-methylimidazolium, 1,3-diethylimidazolium,
  - 20 wherein **R**<sup>A</sup>, **R**<sup>B</sup>, **R**<sup>C</sup>, **R**<sup>1</sup> are each ethyl, and
 

wherein in the aqueous liquid absorption medium **A**<sub>VE</sub> the ratio of the total weight of all trialkyl phosphates of structure (I) to the total weight of all salts **S** is in the range 1:9999 to 1:9.
2. Process according to Claim 1, wherein in the aqueous liquid absorption medium **A**<sub>VE</sub> the total weight of all trialkyl phosphates of structure (I) and all salts **S** is in the range 65 wt% to 95 wt%
 

25 based on the total weight of the aqueous solution.
3. Apparatus **V**<sub>2</sub> for dehumidifying a moist gas mixture, comprising the components
  - (i) an aqueous liquid absorption medium **A**<sub>VO</sub> which comprises a mixture of at least one trialkyl phosphate of structure (I) where



(I)

and at least one salt **S** selected from the group consisting of  $\text{Q}^+(\text{R}^1\text{O})_2\text{PO}_2^-$ ,

- (ii) at least one water absorption unit **W<sub>abs2</sub>** set up for contacting the moist gas mixture with the aqueous liquid absorption medium **A<sub>vo</sub>**,
- 5 (iii) at least one water desorption unit **W<sub>des2</sub>** which comprises a heat exchanger **W<sub>x2</sub>** and is set up for at least partially removing water from an aqueous liquid absorption medium **A<sub>vo</sub>**,
- (iv) and a circuit **U<sub>2</sub>** which connects the water absorption unit **W<sub>abs2</sub>** with the water desorption unit **W<sub>des2</sub>** and by means of which the aqueous liquid absorption
- 10 medium **A<sub>vo</sub>** may be circulated,

wherein at least one of the components water absorption unit **W<sub>abs2</sub>**, water desorption unit **W<sub>des2</sub>**, circuit **U<sub>2</sub>** at least partially comprises a surface made of a steel material of construction **O<sub>st</sub>**, and

15 wherein disposed in the apparatus **V<sub>2</sub>** is at least one contact surface at which the aqueous liquid absorption medium **A<sub>vo</sub>** contacts the surface made of a steel material of construction **O<sub>st</sub>**,

wherein

**Q<sup>+</sup>** is 1-ethyl-3-methylimidazolium, 1,3-diethylimidazolium,

wherein **R<sup>A</sup>**, **R<sup>B</sup>**, **R<sup>C</sup>**, **R<sup>1</sup>** are each ethyl, and

20 wherein in the aqueous liquid absorption medium **A<sub>vo</sub>** the ratio of the total weight of all trialkyl phosphates of structure (I) to the total weight of all salts **S** is in the range 1:9999 to 1:9.

- 4. Apparatus **V<sub>2</sub>** according to Claim 3, wherein in the aqueous liquid absorption medium **A<sub>vo</sub>** the total weight of all trialkyl phosphates of structure (I) and all salts **S** is in the range 65 wt% to 95 wt% based on the total weight of the aqueous solution.
- 25 5. Absorption heat pump, comprising an apparatus **V<sub>2</sub>** according to Claim 3 or 4 and, as further components, a condenser, an evaporator and a coolant, wherein the coolant is water.