ready to absorb water molecules. This operation can be continuous or stepwise.

In recent years an increased focus on process economics has led to improvements in dehumidifier designs focusing amongst other elements on the reuse of the energy content of the warm and humid regeneration air rather than merely discarding it to the atmosphere.

It is an aim of the present invention to suggest an improved system for regenerating a desiccant wheel wherein the regeneration air in the form of superheated steam is used for further purposes in a process stream associated with the desiccant wheel.

US 3,183,649 describes a dehumidifier system comprising a rotary desiccant wheel which comprises a first means to supply a supply gas to an adsorption section of the desiccant wheel, second means to supply superheated steam to a regeneration section of the desiccant wheel, and a third means to supply a flush gas to a flush section.

EP 0014895 discloses an apparatus for producing liquid water from moisture in the air by adsorbing the moisture on an adsorbent and then desorbing water from the adsorbent by heating it and condensing steam into liquid water. The water producing apparatus comprises a recycling passage for recycling steam through an adsorbent column in the desorbing step, a heater for heating the steam in the recycling passage; and a condenser branched from the recycling passage. In the desorbing step, steam in the recycling passage is heated by the heater to heat the adsorbent and to desorb water from the adsorbent and excess of steam corresponding to

the desorbed steam is passed from the recycling passage to the branched condenser and is condensed to obtain liquid water in high efficiency.

WO 2008/044932 describes a dehumidifier system comprising a zeolite rotary desiccant wheel which comprises a first means to supply a supply gas to an adsorption section of the desiccant wheel, a second means to supply superheated steam to a regeneration section of the desiccant wheel, and a third means to supply a flush gas to a flush section, whereby each of the first, second and third means comprises a ventilator or compressor. In an embodiment of the invention of the prior art the superheated steam circulates the zeolite rotary desiccant wheel in a closed-loop regeneration system thus creating an ever increasing surplus of steam with each

regeneration cycle. In order to dispose of the surplus moisture the inventors of WO 2008/044932 suggest passing the excess of superheated steam through a heat exchanger to preheat the supply gas intended to be dried in the zeolite rotary desiccant wheel. Thereby, however, energy needed to maintain the temperature of the superheated steam is lost from the closed regeneration loop. Figure 1 shows the dehumidifier of the prior art.

An advantage to the use of zeolite rotary desiccant wheels with superheated steam is given by the adsorption properties of zeolites at the high temperatures. However the regeneration of zeolite rotary desiccant wheels are less efficient unless steam temperatures in excess of 200°C are used for regenerating the zeolite rotary desiccant wheel as the adsorption capacity of zeolites do not fall significantly below 5 wt% adsorbed water at lower temperatures. This increases energy consumption for heating the superheated steam to an adequate operating temperature, which can be difficult to maintain in an operating environment and heat loss from the regeneration flow path may be significant. Further such high operating temperatures also require heating of any supply gas entering the desiccant wheel in order not to cool the zeolite desiccant wheel below an efficient operating temperature for the intended steam recovery. Thereby a part of the energy advantage of using superheated steam for regeneration of a zeolite rotary desiccant wheel is lost.

~~It is an aspect~~ Embodiments of the present invention ~~to~~ improve the energy efficiency of the systems of the prior art by suggesting further uses for the excess of superheated steam generated in a closed-loop regeneration system

based on superheated steam. ~~It is further an aspect~~ Further embodiments of the present invention ~~to~~ present an improved dehumidifier system for use with other rotary desiccant wheels besides zeolites, preferably rotary desiccant wheels for silica gels and/or activated alumina.

~~In one aspect,~~ Embodiments of the present invention ~~therefore~~ relate~~s~~ to the regeneration of a silica gel rotary desiccant wheel using a closed-loop regeneration system based on superheated steam wherein excess superheated steam and energy generated during regeneration of the desiccant wheel is used in further energy requiring processes within the environment wherein the dehumidifier system of the present invention is installed. Thereby the superior absorption ability for water of silica gel or activated alumina desiccants used in rotary desiccant wheels can be combined with a closed-loop superheated steam recovery of such rotary desiccant wheels at lower operating temperatures and an increase energy gain from the regeneration process.

## BRIEF DESCRIPTION OF THE INVENTION

~~In a first aspect of the present invention there is disclose a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400), said dehumidifier system (200,300,400) comprising a rotary desiccant wheel (210); a supply gas flow path (220) for supplying a supply gas to an adsorption section (211) of said rotary desiccant wheel (210) defining thereby an upstream side (221) and a front side (215) of said rotary desiccant wheel (210), and a downstream side (222) and a backside (216) of said rotary desiccant wheel (210); and a closed regeneration loop~~

~~(240,340,440) for regenerating said rotary desiccant wheel (210) using superheated steam; and said closed regeneration loop (240,340,440) comprising at least one means for circulating superheated steam (250,350,450) in said closed regeneration loop (240,340,440), at least one steam superheater (260,360,460), and at least one diversion flow path (270,370,470) for diverting a flow of excess superheated steam from said closed regeneration loop (240,340,440) to at least one process element of interest (280), said at least one process element of interest (280,380,480) configured to transform excess energy stored in said flow of excess superheated steam into work or heating or cooling or a combination thereof; with the proviso that when said rotary desiccant wheel is a zeolite rotary desiccant wheel, said at least one process element of interest is not a heat exchanger for heating a supply gas arranged in a flow path for a supply gas upstream of said zeolite rotary desiccant wheel.~~

According to an aspect of the present invention, there is provided a dehumidifier system and a dehumidifier comprising said dehumidifier system, said dehumidifier system comprising a rotary desiccant wheel comprising a silica gel; a supply gas flow path for supplying a supply gas to an adsorption section of said rotary desiccant wheel defining thereby an upstream side and a front side of said rotary desiccant wheel, and a downstream side and a backside of said rotary desiccant wheel; and a closed regeneration loop for regenerating said rotary desiccant wheel using superheated steam; and said closed regeneration loop comprising at least one means for circulating superheated steam in said closed regeneration loop, at least one steam superheater, at least one diversion flow path for diverting a flow of excess

superheated steam from said closed regeneration loop to at least one process element of interest, said at least one process element of interest being a heat exchanger or a heat driven cooling unit; and wherein said closed regeneration loop is operated at a regeneration operating temperature of said superheated steam from 110°C to 200°C.

In an ~~first~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400), wherein~~ the flow direction of said superheated steam is countercurrent to the flow direction of said supply gas, wherefore said superheated steam circulating in said closed regeneration loop ~~(240,340,440)~~ will reach a regeneration section ~~(214)~~ of said rotary desiccant wheel ~~(210)~~ from said backside ~~(216)~~ of said rotary desiccant wheel.

In an ~~second~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400), wherein~~ the flow direction of said

superheated steam is co-current to the flow direction of said supply gas, wherefore said superheated steam circulating in said closed regeneration loop ~~(240,340,440)~~ will reach a regeneration section ~~(214)~~ of said rotary desiccant wheel ~~(210)~~ from said front side ~~(215)~~ of said rotary desiccant wheel.

In an ~~third~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, further comprising~~ the above dehumidifier system further comprises a flush and heating flow path ~~(230)~~ for supplying a first flush gas to a flush and heating section ~~(212)~~ of said rotary desiccant wheel ~~(210)~~ and/or a flush and cooling flow path ~~(235)~~ for supplying a second flush gas to a flush and cooling section ~~(212)~~ of said rotary desiccant wheel ~~(210)~~;

In an ~~fourth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein~~ said first flush gas and said second flush gas are the same, preferably the same as said supply gas.

In an ~~fifth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein~~ said flush and heating flow path ~~(230)~~, and said flush and cooling flow path ~~(235)~~, are connected to form a unified flush flow path ~~(236,237,336,337,436,437)~~; preferably connected to form a unified flush flow path either upstream ~~(237,337,437)~~ from said rotary desiccant

wheel ~~(210)~~ and/or downstream ~~(236,336,436)~~ from said rotary desiccant wheel.

In an ~~sixth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, comprising~~ the above humidifier system comprises at least one further flush and heating flow path ~~(230)~~ and/or at least one further flush and cooling flow path ~~(235)~~.

~~In a seventh embodiment of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein said rotary desiccant wheel (210) comprises a silica gel, a zeolite, an activated alumina, preferably a silica gel or an activated alumina, more preferably a silica gel.~~

In an ~~eight~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein~~ said rotary desiccant wheel ~~(210)~~ comprises a combination of adsorbents, preferably of silica gel and zeolite as a mixture; or as alternating layers of two or more of said adsorbents, preferably alternating layers of silica gel and zeolite.

~~In a ninth embodiment of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments,~~

~~wherein the regeneration operating temperature of said superheated steam is from 100°C to 250°C, preferably from 110°C to 200°C, most preferably from 130°C to 150°C.~~

In an ~~tenth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein~~ the regeneration operating steam pressure of said superheated steam is from 1 bar to 5 bars, preferably from 1 bar to 3 bars, more preferably from 1 bar to 2 bars, most preferable from 1.05 bars to 1.5 bars.

~~In an eleventh embodiment of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein said at least one process element of interest (280,380,480) is a heat exchanger (380) or a heat driven cooling unit (480).~~

~~In a twelfth embodiment of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein said rotating desiccant wheel comprises silica gel and/or activated alumina and said dehumidifier system is operated at a regeneration operation temperature between 110°C to 200°C, more preferably operated at a regeneration operation temperature between 120°C to 180°C, most preferably from 130°C to 150°C.~~

In an ~~thirteenth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a~~

~~dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein~~ the temperature of said supply gas upon entry into said rotary desiccant wheel ~~(210)~~ is from 5°C to 100°C, preferably from 10°C to 60°C, preferably from 20°C to 50°C, preferably from 30°C to 40°C.

In an ~~fourteenth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, further comprising~~ the above dehumidifier system further comprises at least one underpressure section ~~(590,591,592,593,594)~~.

In an ~~fifteenth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein~~ excess superheated steam from said closed regeneration loop ~~(340)~~ for superheated steam regeneration of said rotary desiccant wheel ~~(210)~~ is diverted from said closed regeneration loop ~~(340)~~ along said diversion flow path ~~(370)~~ to said at least one process element of interest ~~(380)~~, said at least one process element of interest ~~(380)~~ being a heat exchanger ~~(380)~~, preferably a condenser, comprised in said closed regeneration loop ~~(340)~~, preferably said heat exchanger ~~(380)~~ arranged in said closed regeneration loop ~~(340)~~ between said at least one means for circulating superheated steam ~~(350)~~ and said steam superheater ~~(360)~~.

In an ~~sixteenth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (300) and a dehumidifier comprising said dehumidifier system (300) according to~~

~~the fifteenth embodiment of the first aspect, further comprising~~ the above dehumidifier system further comprises in said diversion flow path ~~(370)~~ at least one compressor ~~(381)~~ for compressing in at least on compression step said excess superheated steam prior to entering said heat exchanger ~~(380)~~.

In an ~~seventeenth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system (200,300,400) and a dehumidifier comprising said dehumidifier system (200,300,400) according to any preceding embodiments, wherein~~ excess superheated steam from a closed regeneration loop ~~(440)~~ for superheated steam regeneration of a rotary desiccant wheel ~~(210)~~ is diverted from said closed regeneration loop ~~(440)~~ along a diversion flow path ~~(470)~~ to at least one heat driven cooling unit ~~(480a,480b)~~ located either upstream ~~(480a)~~ or downstream ~~(480b)~~ of said rotary desiccant wheel ~~(210)~~ in a gas flow path ~~(220,230,235)~~, preferably located in said supply gas flow path ~~(220)~~.

In an ~~eighteenth~~ embodiment, ~~of the first aspect there is disclosed a dehumidifier system,~~ said dehumidifier system comprising a first dehumidifier system ~~(200,300,400)~~, said first dehumidifier system ~~(200,300,400)~~ comprising a closed regeneration loop ~~(240,340,440)~~ for regenerating a rotary desiccant wheel ~~(210)~~ using superheated steam according to any of the preceding embodiments, and at least a second dehumidifier system, said second dehumidifier system comprising at least one second rotary desiccant wheel, said at least one second dehumidifier system not comprising a closed regeneration loop for regenerating said at least one second rotary desiccant wheel using superheated steam, wherein said first dehumidifier system ~~(200,300,400)~~ and said at least a

second dehumidifier system are arranged sequentially on said supply gas flow path ~~(220)~~, preferably arranged sequentially with said first dehumidifier system ~~(200,300,400)~~ arranged upstream ~~(221)~~ of said at least a second dehumidifier system on said supply gas flow path ~~(220)~~.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1: A dehumidifier system of the prior art.

Figure 2: An exemplary dehumidifier system according to the invention.

Figure 3: An exemplary dehumidifier system for recovering latent heat of evaporation.

Figure 4: An exemplary dehumidifier system comprising a heat driven refrigeration unit.

Figure 5: An exemplary rotary desiccant wheel comprising underpressure sections.

DETAILED DESCRIPTION

The present invention relates to novel dehumidifier systems and novel dehumidifiers comprising said novel dehumidifier systems, each comprising a closed regeneration loop for regenerating a rotary desiccant wheel using superheated steam; and uses of excess superheated steam generated during regeneration.

CLAIMS:

1. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~, said dehumidifier system ~~(200,300,400)~~ comprising
   - a rotary desiccant wheel ~~(210)~~ comprising a silica gel;
   - a supply gas flow path ~~(220)~~ for supplying a supply gas to an adsorption section ~~(211)~~ of said rotary desiccant wheel ~~(210)~~ defining thereby an upstream side ~~(221)~~ and a front side ~~(215)~~ of said rotary desiccant wheel ~~(210)~~, and a downstream side ~~(222)~~ and a backside ~~(216)~~ of said rotary desiccant wheel ~~(210)~~; and
   - a closed regeneration loop ~~(240,340,440)~~ for regenerating said rotary desiccant wheel ~~(210)~~ using superheated steam; and
   - said closed regeneration loop ~~(240,340,440)~~ comprising
     - at least one means for circulating superheated steam ~~(250,350,450)~~ in said closed regeneration loop ~~(240,340,440)~~,
     - at least one steam superheater ~~(260,360,460)~~,
     - at least one diversion flow path ~~(270,370,470)~~ for diverting a flow of excess superheated steam from said closed regeneration loop ~~(240,340,440)~~ to at least one process element of interest ~~(280)~~, said at least one process element of interest ~~(280,380,480)~~ being a heat exchanger ~~(380)~~ or a heat driven cooling unit ~~(480)~~; and
   - wherein said closed regeneration loop is operated at a regeneration operating temperature of said superheated steam from 110°C to 200°C.

2. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to claim 1, wherein the flow direction of said superheated steam is countercurrent to the flow direction of said supply gas, wherefore said superheated steam circulating in said closed regeneration loop ~~(240,340,440)~~ will reach a regeneration section ~~(214)~~ of said rotary desiccant wheel ~~(210)~~ from said backside ~~(216)~~ of said rotary desiccant wheel.

3. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to claim 1, wherein the flow direction of said superheated steam is co-current to the flow direction of said supply gas, wherefore said superheated steam circulating in said closed regeneration loop ~~(240,340,440)~~ will reach a regeneration section ~~(214)~~ of said rotary desiccant wheel ~~(210)~~ from said front side ~~(215)~~ of said rotary desiccant wheel.

4. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to any of the claims 1 to 3, further comprising a flush and heating flow path ~~(230)~~ for supplying a first flush gas to a flush and heating section ~~(212)~~ of said rotary desiccant wheel ~~(210)~~ and/or a flush and cooling flow path ~~(235)~~ for supplying a second flush gas to a flush and cooling section ~~(212)~~ of said rotary desiccant wheel ~~(210)~~;

5. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to any of the claims 1 to 4, wherein said first flush gas and said second flush gas are the same, preferably the same as said supply gas.

6. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to any of the claims 4 or 5, wherein said flush and heating flow path ~~(230)~~, and said flush and cooling flow path ~~(235)~~, are connected to form a unified flush flow path ~~(236,237,336,337,436,437)~~; preferably connected to form a unified flush flow path either upstream ~~(237,337,437)~~ from said rotary desiccant wheel ~~(210)~~ and/or downstream ~~(236,336,436)~~ from said rotary desiccant wheel.

7. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to any of the claims 1 to 6, comprising at least one further flush and heating flow path ~~(230)~~ and/or at least one further flush and cooling flow path ~~(235)~~.

8. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to any of the claims 1 to 7, wherein said rotary desiccant wheel ~~(210)~~ comprises a combination of adsorbents, preferably of silica gel and zeolite as a mixture; or as alternating layers of two or more of said adsorbents, preferably alternating layers of silica gel and zeolite.

9. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to any of the claims 1 to 8, wherein the regeneration operating steam pressure of said superheated steam is from 1 bar to 5 bars, preferably from 1 bar to 3 bars, more preferably from 1 bar to 2 bars, most preferable from 1.05 bars to 1.5 bars.

10. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to any of the claims 1 to 9, wherein the temperature of said supply gas upon entry into said rotary desiccant wheel ~~(210)~~ is from 5°C to 100°C, preferably from 10°C to 60°C, preferably from 20°C to 50°C, preferably from 30°C to 40°C.

11. A dehumidifier system ~~(200,300,400)~~ and a dehumidifier comprising said dehumidifier system ~~(200,300,400)~~ according to any of the claims 1 to 10, further comprising at least one underpressure section ~~(590,591,592,593,594)~~.

12. A dehumidifier system ~~(300)~~ and a dehumidifier comprising said dehumidifier system ~~(300)~~ according to any of the claims 1 to 11, wherein excess superheated steam from said closed regeneration loop ~~(340)~~ for superheated steam regeneration of said rotary desiccant wheel ~~(210)~~ is diverted from said closed regeneration loop ~~(340)~~ along said diversion flow path ~~(370)~~ to said at least one process element of interest ~~(380)~~, said at least one process element of interest ~~(380)~~ being a heat exchanger ~~(380)~~, preferably a condenser, comprised in said closed regeneration loop ~~(340)~~, preferably said

heat exchanger ~~(380)~~ arranged in said closed regeneration loop ~~(340)~~ between said at least one means for circulating superheated steam ~~(350)~~ and said steam superheater ~~(360)~~; and wherein said diversion flow path ~~(370)~~ comprises at least one compressor ~~(381)~~ for compressing in at least on compression step said excess superheated steam prior to entering said heat exchanger ~~(380)~~.

13. A dehumidifier system ~~(400)~~ and a dehumidifier comprising said dehumidifier system ~~(400)~~ according to any of the claims 1 to 12, wherein excess superheated steam from a closed regeneration loop ~~(440)~~ for superheated steam regeneration of a rotary desiccant wheel ~~(210)~~ is diverted from said closed regeneration loop ~~(440)~~ along a diversion flow path ~~(470)~~ to at least one heat driven cooling unit ~~(480a,480b)~~ located either upstream ~~(480a)~~ or downstream ~~(480b)~~ of said rotary desiccant wheel ~~(210)~~ in a gas flow path ~~(220,230,235)~~, preferably located in said supply gas flow path ~~(220)~~.

14. A dehumidifier system, said dehumidifier system comprising a first dehumidifier system ~~(200,300,400)~~ according to claims 1 to 13, said first dehumidifier system ~~(200,300,400)~~ comprising a closed regeneration loop ~~(240,340,440)~~ for regenerating a rotary desiccant wheel ~~(210)~~ using superheated steam, and at least a second dehumidifier system, said second dehumidifier system comprising at least one second rotary desiccant wheel, said at least one second dehumidifier system not comprising a closed regeneration loop for regenerating said at least one second rotary desiccant wheel using

superheated steam, wherein said first dehumidifier system ~~(200,300,400)~~ and said at least a second dehumidifier system are arranged sequentially on said supply gas flow path ~~(220)~~, preferably arranged sequentially with said first dehumidifier system ~~(200,300,400)~~ arranged upstream ~~(221)~~ of said at least a second dehumidifier system on said supply gas flow path ~~(220)~~.