

Drying Compressed Air Using Compressor Heat in a sealed regeneration cycle

The present invention relates to a facility for drying compressed air according to the features (a) to (h) of claim 1. Further, the invention relates to a method for regenerating an adsorption container of such a facility.

5 In present facilities at least two parallel connected drying agent filled adsorption containers are alternately driven in adsorption or regeneration mode. The drying agent dries the compressed air to be dried in the adsorption mode, the moisture-laden drying agent is first dried by desorption and then cooled in the regeneration mode. The drying of the drying agent is carried out by using the
10 heat which is contained in the moist compressed air to be dried. Said heat is generated by the work done on compression of the compressor not belonging to the facility which compresses the moist ambient air to the compressed air to be dried.

15 In the known state of the art it is intended to desorb the bound moisture in the drying agent of the adsorption container which is in the regeneration mode by a hot stream of compressed air, and to cool it after releasing the bound moisture by a cooler stream of compressed air, wherein the cooler stream of compressed air is saturated with moisture.

20 A method flow chart of a generic facility is shown in figures 1 and 2 in different phases:

Fig. 1: Known facility in the desorption phase (state of the art);

Fig. 2: Known facility in the cooling phase (state of the art).

25 The facility for drying compressed air shown in figures 1 and 2 is connected via an entrance 1 and an exit 2 to a compressor 9 not belonging to the facility and to a compressed air pipework not shown, respectively. The compressor 9 intakes

moist ambient air and compresses it. The moist compressed air 8 to be dried enters the facility through entrance 1. The facility comprises two parallel connected adsorption containers 3, 4, one 3 of them is always in the adsorption mode while the other 4 is in the regeneration mode. Within all figures described here, the left adsorption container 3 is in the adsorption mode, while the right adsorption container 4 is either in the regeneration mode or in a standby mode. The regeneration involves the consecutive steps of desorption and cooling.

In figure 1 the right adsorption container is desorbed. For this purpose, moist compressed air 8 is passed as a desorption stream of compressed air via an inlet conduit 10 through the right container 4. In doing so, the drying agent contained in the container 4 transfers its moisture to the desorption stream of compressed air. This is possible because of the heat within the compressed air 8 to be dried which is generated by the compression process in the compressor 9. The actuators 11 of the facility are connected in a way such that the stream of compressed air further is cooled by a cooler 12 and the thereby condensed water is precipitated in a mist collector 13. Therefore, the moisture extracted from the compressed air 8 to be dried exits the facility via the mist collector 13. The compressed air 8 to be dried is then passed through the left adsorption container 3 which is in the adsorption mode. The drying agent contained therein adsorbs the moisture so that dry compressed air 14 is produced. The dry compressed air 14 is conducted via an outlet conduit 15 to the exit 2 and is from that point feeded in the compressed air pipework not shown.

In the cooling phase shown in figure 2 the actuators 11 are connected in such a way that the stream of moist compressed air 8 conducted through the inlet conduit 10 first is cooled in the cooler 12, then is condensed in the mist collector 13 and afterwards is passed through the right container 4 as a cooling stream of compressed air. Since the cooling stream of compressed air has adsorbed the heat of the freshly desorped drying agent, it must be conducted through an auxilliary cooler 5 before the moist compressed air 8 can be dried in the left adsorption container 3. The now dried compressed air 14 is conducted via the outlet conduit 15 to the exit 2 and thence is feeded in the pipework.

The above described drying facilities are disadvantageous in that the desorption phase as well as the cooling phase could only be carried out when a stream of compressed air from the compressor 9 to the compressed air load exists. This means that the compressor 9 must be already in use when the facility is started to generate the necessary compression heat for the initial desorption. The compressed air which leaves the not yet completely conditioned facility is not of the necessary quality that is required for sensitive applications in the pharmaceutical industry, food industry or semiconductor industry. Therefore, the compressed air which is energy-intensively generated during the start of the facility has to be blown off. Through this, not only energy but also time is lost.

In view of the state of the art shown in figures 1 and 2 it is the object of the present invention to provide a facility for drying compressed air which yields dried compressed air of higher quality without an additional time or energy expense.

This object is solved in that the facility comprises a return conduit which is connectable from the adsorption container in the regeneration mode to the inlet conduit in such a way that a branch current of dry compressed air is branchable via the branch current conduit ahead of the exit, is passable through the adsorption container which is in the regeneration mode as a stream of compressed air, and is lastly via the return conduit refeedable into the stream of the moist compressed air to be dried.

To enable this refeeding a pressure increasing pump is arranged on the branch current conduit with which the pressure of the branch current of the dry compressed air is increasable. In this way, the pressure drop in the adsorption container which is in the regeneration mode is compensated so that a refeeding of the branch current into the main current is possible.

In the facility the cooling phase is carried out by using already dried air. But this air is not lost. Due to the pressure increasing pump the branched branch current can be feeded into the main current which gets to the drying. This brings two essential advantages: By the cooling of the drying agent with dried compressed

air the physical ratios in the adsorber change. After the completed desorption phase with hot but moisture-laden compressed air the drying agent and the desorption stream of compressed air are balanced. The compressed air to be dried comprises a significant lesser partial pressure of water vapour. The now
5 dominating difference in partial pressure between the cooling air stream and the drying agent causes as driving force a after-desorption of the adsorbition. By the after-desorption the remaining load of water molecules in the drying agent is reduced. The remaining load of the drying agent is preferential responsible for the quality of the compressed air drying. Therefore, an increase in quality is
10 given without additional heating energy. Moreover, an additional auxilliary cooler for recooling of the cooling air stream is not necessary.

According to an advantageous embodiment of the invention the branch conduit passes through a heat exchanger before ending in the adsorption container which is in the regeneration mode. The heat exchanger is used for heating and
15 cooling of the branch current of the dry compressed air. Through this, the desorption and accordingly the cooling is enhanced.

The heat which is transferred to the branch current by the heat exchanger is obtained from an external heating medium or from the already existing compressor heat.

20 For using the compressor heat the heat of the moist compressed air to be dried is transferred in the heat exchanger to the branch current of dry compressed air conducted through the branch current conduit.

A spezial advantage is given by heating the branch current with the help of heat of an optional external heating medium. The external heat is preferably always
25 switched on when the quality of the dry compressed air leaving the facility is still not sufficient to correspond to the quality requirement of the application. In particular, this is the case when the facility is started. All known facilities of the state of the art in which the desorption is carried out by using compression heat or by means of another heated compression air stream, the method steps
30 „desorption“ and „cooling“ can only by carried out when the compression air

streams. A so called „Start up“, in which the drying agent is brought in a defined condition, is not possible. Until now, in the starting phases either a less quality was accepted or the expensively compressed compressed air was blown off after the adsorption container until the required quality is achieved. The heat exchanger of this embodiment of the invention, which supplies external heat to the branch current, is switched off during the normal operation mode. It is only switched on when the facility is started so that the conditioning of the adsorption containers is significantly faster and is carried out without losing compressed air.

Two embodiments of the present invention are now demonstrated by means of method flow charts. For this purpose:

Fig. 3: shows a first embodiment of a facility according to the invention in the desorption phase;

Fig. 4: shows a facility according to figure 3 in the cooling phase;

Fig. 5: shows a facility according to figure 3 in a alternative desorption phase;

Fig. 6: shows a facility according to figure 3 in the standby phase;

Fig. 7: shows a second embodiment of the facility according to the invention in the desorption phase;

Fig. 8: shows the facility according to figure 7 in the cooling phase;

Fig. 9: shows the facility according to figure 7 in the standby phase.

A first embodiment of a facility for drying compressed air according to the present invention is shown in figures 3, 4, 5 and 6 in different phases. Moist compressed air 8, which is compressed from ambient air by a compressor 9 that

does not belong to the facility, enters the facility through entrance 1. The compressor 9 is constructed without an after-cooler so that the entering moist compressed air 8 is warmer than the ambient air. The inlet conduit 10 branches directly behind the entrance 1 and is on both sides to each one of the two parallel connected adsorption container 3, 4 by means of a plurality of actuators 11.

Within the standby mode shown in figure 3, the left adsorption container 3 is in the adsorption phase and the right adsorption container 4 is in the regeneration phase, more precisely in the desorption phase. For carrying out desorption, warm compressed air 8 to be dried is conducted along the inlet conduit 10 through the right adsorption container 4 to carry out desorption. Through this, the drying agent in the right adsorption container 4 is heated so that the water contained therein vaporises. The warm with water vapour loaded compressed air stream is cooled in a cooler 12. The thereby condensed moisture is skimmed off with a mist collector 13. The compressed air stream 8 to be dried is now conducted through the adsorption container 3 which is in the adsorption mode so that the product of the drying process – dry compressed air 14 – is generated. The dry compressed air 14 streams along a outlet conduit 15 to the exit 2.

Directly ahead of the exit 2 a branch current conduit 16 branches from the outlet conduit 15, which is needed for the cooling phase shown in figure 4. In the cooling phase a branch current 7 of the dry compressed air 14 is feeded in the facility by means of the branch current conduit 16 for cooling purposes. For this, firstly the pressure of the branch current 7 is increased by means of a pressure increasing pump 17. As the case may be, the branch current conduit 16 passes through a heat exchanger 18, in which the branch current 7 additionally can be cooled by means of an external cooling medium, if required. Normally, this will not be necessary. The branch current 7 is now conducted through the right adsorption container 4 and cools the drying agent contained therein so that it will be deployable again. The branch current 7 is added after the container 4, which is in cooling phase, at position 19 to the stream of the compressed air 8 to be dried into the inlet conduit 10. This stream passes then again through the adsorbing container 3.

Figure 5 shows an alternative desorption phase during the start of the facility, in which the dried compressed air 14 has not yet reached the required quality for first sufficiently conditioning the right adsorption container 4. Here – in contrast to the desorption phase under going operation shown in figure 3 – the pressure increasing pump 17, which is otherwise only needed in the cooling phase (Fig. 4), is switched on and a branch current 7 is branched. This branch current 7 is heated in the heat exchanger 18 with heat of an external heating medium so as to carry out desorption of the right adsorption container. The entire facility is not streamed during this phase, but is merely under operation pressure.

10 In figure 6, the right adsorption container 4 has completely released its water load and is in standby. Thereby, it is not streamed with compressed air. A branching of a branch current of dry compressed air 14 is not necessary. The whole volume flow of the inflowing moist compressed air 8 is discharged in its entirety out of the exit 2 without an internal circulation in the facility.

15 Figures 7 to 9 show a second embodiment of the facility for drying compressed air according to the invention. It differs from the first embodiment in the way of conducting the desorption stream of compressed air. For desorption (figure 7) a branch current 7 of dry compressed air 14 is branched directly ahead of the exit 2 by means of a branch current conduit 16 branching from the outlet conduit 15.

20 The pressure of the branch current 7 is increased by means of a pressure increasing pump 17 which is arranged in the branch current conduit 16. Afterwards, the branch current 7 passes through a heat exchanger 18 in which the branch current 7 is preheated by means of compression heat of the compressor 9.

25 For this, the moist warm compressed air 8 is conducted directly behind its entrance in the facility through entrance 1 along a inlet conduit 10 through the heat exchanger 18. There, the compression heat contained in the moist compressed air 8 is transferred to the branch current 7 of the dry compressed air 14. The branch current 7, being preheated in this way, is conducted for

30 desorption through the right container 4 and subsequently is refeeded at position 19 in the inlet conduit 10 so that the branch current 7 of the dry compressed air is again added to the moist compressed air 8. As in the first embodiment of the

invention, the moist compressed air 8 is now cooled by a cooler 12, is then condensed in a mist collector 13, is dried by adsorbing adsorption container 3, and is conducted away through the outlet conduit 15 of the facility.

5 A commonness of the first and the second embodiments of the invention is that the branch current 7 is used for cooling the right adsorption container 4. According to this, the actuators 11 are switched in the cooling phase of the second embodiment (figure 8) in such a way, that the inlet conduit 10 is not directed through the heat exchanger 18. The pressure increasing pump 17 runs during the cooling phase to feed the branch current 7 on compressor level at 19
10 into the inlet conduit 10.

In the standby mode (figure 9), the pressure increasing pump 17 is switched off so that the standby container 4 is not streamed.

15 A further commonness of both embodiments is the utilisation of the compressor heat for desorption. In the first facility (figure 3), the heat of the compressor is directly transferred from the moist compressed air 8 to be dried to the drying agent. In the second facility (figure 7), the heat of the compressor is skimmed and transferred to the desorbing branch current 7.

Claims

1. Facility for drying compressed air,
 - a) with an entrance (1), through which moist compressed air (8) to be dried enters the facility, and with an exit (2), through which dry compressed air (14) exits the facility,
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 - b) with at least two parallel connected, drying agent filled adsorption containers (3, 4), which are connected via an inlet conduit (10) with the entrance (1) and via an outlet conduit (15) with the exit (2),
 - c) wherein always at least one (3) of said adsorption containers
10 (3, 4) is in the adsorption mode, while at least another (4) is either in the unstreamed standby mode or in the regeneration mode,
 - d) wherein the adsorption container (3) which is in the adsorption mode is streamed by compressed air (8) to be dried and wherein its drying agent adsorbs the moisture of the compressed air (8) to
15 be dried,
 - e) wherein the adsorption container (4) which is in the regeneration mode first is streamed by a desorption stream of compressed air and subsequently by a cooling stream of compressed air,
 - f) wherein the desorption stream of compressed air is heated
20 with heat of the moist compressed air (8) to be dried,
 - g) wherein the desorption stream of compressed air desorbs the moisture bound in the drying agent of the adsorption container (4) which is in the regeneration mode,
 - h) and wherein the cooling stream of compressed air cools the
25 drying agent of the adsorption container (4) which is in the regeneration mode,

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5 i) a branch current conduit (16) branches from the outlet conduit (15) ahead of the exit (2), wherein the branch current conduit (16) passes through a pressure increasing pump (17) and wherein the branch current conduit (16) is connectable with the adsorption container (4) which is in the regeneration mode,

10 j) the facility comprises a return conduit (20), which is connectable from the adsorption container (4) that is in the regeneration mode to the inlet conduit (10),

15 k) in such a way that a branch current (7) of the dry compressed air (14) is branchable ahead of the exit (2) via the branch current conduit (16), wherein the pressure of the branch current (7) is increasable via the pressure increasing pump (17), and wherein the branch current (7) is conductable through the adsorption container (4) that is in the regeneration mode as a cooling stream of compressed air, and wherein the branch current (7) is lastly admixable – via the return conduit (20) connected to the inlet conduit (10) – to the stream of the moist compressed air (8) to be dried.

20 2. Facility according to claim 1, wherein the branch current conduit (16) passes through a heat exchanger (18) before it ends in the adsorption container (4) that is in the regeneration mode.

25 3. Facility according to claim 2, wherein heat of the branch current (7) of the dry compressed air (14) conducted along the branch current conduit (16) is transferable to an external cooling medium.

4. Facility according to claim 2, wherein heat of an external heating medium is transferable to the branch current (7) of the dry compressed air (14) conducted along the branch current conduit (16) by means of the heat exchanger (18).

30 5. Facility according to claim 2, wherein heat of the moist compressed air (8) to be dried is transferable to the branch current (7) of

the dry compressed air (14) conducted along the branch current conduit (16) by means of the heat exchanger (18).

5 6. Method for regenerating of an adsorption container (4) that is in the regeneration mode, which is filled with a drying agent, and which is parallel connected to another adsorption container (3) that is in the adsorption mode, wherein the adsorption container (3) that is in the adsorption mode dries moist compressed air (8) to be dried so that dry compressed air (14) is generated, c h a r a c t e r i z e d i n t h a t
10 a branch current (7) is branched from the dry compressed air (14), the pressure of said branch current (7) is increased, and the branch current (7) is conducted through the adsorption container (4) that is in the regeneration mode and subsequently admixed to the moist compressed air (8) to be dried.

15 7. Method according to claim 6, wherein the drying agent of the adsorption container (4) that is in the regeneration mode is cooled by means of the branch current (7) of the dry compressed air (14).

 8. Method according to 6 or 7, wherein the drying agent of the adsorption container (4) that is in the regeneration mode is dried by means
20 of the branch current (7) of the dry compressed air (14).

 9. Method according to claim 7 or 8, wherein the branch current (7) of the dry compressed air (14), before inflowing in the adsorption container (4) that is in the regeneration mode, is conducted through a heat exchanger (18).

25 10. Method according to claim 9, wherein the branch current (7) of the dry compressed air (14) is cooled in the heat exchanger (18).

 11. Method according to claim 9, wherein the branch current (7) of the dry compressed air (14) is heated in the heat exchanger (18).

12. Method according to claim 11, wherein the branch current (7) of the dry compressed air (14) is heated in the heat exchanger (18) by an external heating medium.

5 13. Method according to claim 11, wherein the branch current (7) of the dry compressed air (14) is heated in the heat exchanger (18) by the moist compressed air (8) to be dried.

10 14. Method for operating a facility according to any of the claims 1 to 5, characterized in that a method according to one of the claims 6 to 13 is used for regenerating the adsorption container (4) which is in the regeneration mode.

15. Dry compressed air (14), dried with a facility according to any of the claims 1 to 5.

16. Dry compressed air (14) according to claim 15, wherein the facility is operated according to a method according to claim 14.