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DESCRIPTION

[0001] The invention relates to a method for the synthesis of methanol in accordance with the preamble of patent claim 1, to a method for converting a plant for the synthesis of methanol in accordance with the preamble of patent claim 15, and also to a plant for the synthesis of methanol in accordance with the preamble of patent claim 16.

[0002] During the production of methanol from natural gas, as a rule, a synthesis gas is obtained from the natural gas in a first step, which synthesis gas is then synthesised into methanol in a subsequent step. A conventional strategy for obtaining the synthesis gas consists of steam reforming the natural gas in a steam reformer with the addition of steam. The synthesis of methanol from the synthesis gas which follows then takes place in a methanol reactor. In addition, in the prior art, the provision of a plurality of steam reformers in order to raise the throughput of a plant for the synthesis of methanol is known, wherein each steam reformer feeds a respective dedicated methanol reactor with the fresh gas flow produced in it. This is referred to as a plurality of strands for the methanol synthesis, wherein each strand comprises a steam reformer and the associated methanol reactor.

[0003] The disadvantage with this strategy is that the synthesis gas produced during steam reforming has a stoichiometry which is not ideal for the synthesis of methanol. Specifically, the synthesis gas produced during the steam reforming has a surplus of hydrogen so that, therefore, the quantitative ratio between hydrogen and the carbon oxides is excessive. Thus, the synthesis gas is described as being over-stoichiometric. This surplus leads to a situation in which a comparatively large amount of unreacted hydrogen leaves the methanol reactor. Because of this, in order to prevent a great deal of unreacted gas which also has to be compressed from reaching the synthesis circuit, which is expensive, a portion of the unreacted hydrogen together with methane which has not been converted into synthesis gas is ejected as a purge gas. As a rule, the purge gas is then used to fire the steam reformer. As a result, because of the combustion of hydrogen which has been produced but not utilised, and because of the increased quantity of gas which is circulating, the energy consumption during the synthesis of methanol, and therefore also the emission of carbon dioxide as a waste gas, is significantly increased with this strategy.

[0004] EP 2 116 295 A1, which constitutes the closest prior art to the present invention, therefore seeks to obtain a more suitable stoichiometry for the methanol synthesis, so that a synthesis gas is not only obtained from natural gas in a steam reformer, but also, the provision is made to obtain more synthesis gas by non-catalytic partial oxidation in a POX reactor. In this regard, the non-catalytic partial oxidation of synthesis gas obtained from natural gas - in contrast to the synthesis gas from steam reforming - is under-stoichiometric and therefore has a deficit of hydrogen. Furthermore, now the synthesis gas from steam reforming here can be mixed with the synthesis gas from the POX reactor in a manner such that the resulting synthesis gas reaches the desired stoichiometry for the synthesis of methanol. Correspondingly, here, the two synthesis gas flows are combined in a common methanol reactor for the synthesis of methanol.

[0005] In principle, this strategy is in fact suitable for obtaining an improved stoichiometric number in the common methanol reactor. However, the strategy is less helpful as regards being able to improve the economic efficiency of plants which are already extant for methanol synthesis based on steam reforming - in particular when they have multiple strands. The revamps to the plant as a whole which are required are in fact too extensive.

[0006] Starting from this prior art, the aim of the invention is consequently to provide a strategy for methanol synthesis which, in addition to improving the economic efficiency by significantly reducing the specific natural gas used for methanol synthesis, enables a simultaneous significant reduction to be made in the emissions of carbon dioxide in the case of extant and in particular multi-sectioned plants based on steam reforming.

[0007] In respect of a method for the synthesis of methanol with the features of the preamble of claim 1, this aim is achieved by means of the features of the characterizing portion of claim 1. In respect of a method for the conversion of a plant for the synthesis of methanol with the features of the preamble of claim 15, this aim is achieved by means of the features of the characterizing portion of claim 15, and in respect of a plant for the synthesis of methanol with the features of the preamble of claim 16, this aim is achieved by means of the features of the characterizing portion of claim 16.

[0008] The basis of the invention is the realisation that even in the case of the separate production of over-stoichiometric gas by steam reforming on the one hand and the production of under-stoichiometric gas by partial oxidation on the other hand, it is nevertheless advantageous to initially also supply the corresponding fresh gas flows to separate methanol reactors. Thus, the fresh gas flows remain in their respective strands. The stoichiometry can then be adjusted because a portion of the residual gas from the methanol reactor from steam reforming, which still has an excess of hydrogen, is supplied to the methanol reactor for partial oxidation, and in fact directly or indirectly. Thus, only the residual gas is branched off from one strand to another. In this manner, in order to improve the economic efficiency, it is only necessary to provide a reactor for the partial oxidation as well as an associated methanol reactor in addition to or instead of an extant steam reformer and the associated methanol reactor. All of the other strands, formed by a steam reformer and methanol reactor, can be left substantially unmodified.

[0009] In this regard, supplying the hydrogen to the under-stoichiometric methanol reactor for the partial oxidation may be carried out in different manners. The dependent claims 3, 5 and 6 define both direct as well as indirect variations.

[0010] As defined in dependent claim 8, here too, a portion of the unreacted hydrogen may be used to fire the steam reformer, wherein the dependent claim 9 describes advantageous proportions. According to dependent claim 11, residual gas from the methanol reactor for partial oxidation may also be used for such firing.

[0011] Dependent claim 12 describes preferred embodiments which provide for a particularly effective utilisation of the compressors. Because the energy consumption during pressure boosting constitutes a particularly relevant cost factor, savings in this area become significant when evaluating economic efficiency.

[0012] A reduction in the process gas to be supplied and circulated can also be obtained by carrying out the partial oxidation with a flow of oxygen which has been obtained from an air separation step. This is defined in dependent claim 13.

[0013] Finally, dependent claim 14 concerns a scenario with more than two sections for the methanol synthesis.

[0014] Preferred embodiments, features and advantages of the method in accordance with the invention for the synthesis of methanol correspond to preferred embodiments, features and advantages of the plant in accordance with the invention for the synthesis of methanol as well as to the method in accordance with the invention for the conversion of a plant for the synthesis of methanol, and vice versa.

[0015] Further details, features, aims and advantages of the present invention will now be described with the aid of the drawings which are given solely by way of exemplary embodiments. In the drawings:

Figure 1 shows a diagrammatic representation of a first exemplary embodiment of the proposed plant for the synthesis of methanol for carrying out the proposed method for the synthesis of methanol,

Figure 2 shows a diagrammatic representation of a second exemplary embodiment of the proposed plant for the synthesis of methanol for carrying out the proposed method for the synthesis of methanol,

Figure 3 shows a diagrammatic representation of a third exemplary embodiment of the proposed plant for the synthesis of methanol for carrying out the proposed method for the synthesis of methanol,

Figure 4 shows a diagrammatic representation of an adiabatic quench reactor for methanol synthesis as a component of the respectively proposed plant of Figures 1 to 3 as well as 6,

Figure 5 shows a diagrammatic representation of an isothermal reactor for methanol synthesis as a component of the respectively proposed plant of Figures 1 to 3 as well as 6, and

Figure 6 shows a diagrammatic representation of a fourth exemplary embodiment of the proposed plant for the synthesis of methanol for carrying out the proposed method for the synthesis of methanol.

[0016] The proposed method for the synthesis of methanol 1 may be carried out by one of the proposed plants for the synthesis of methanol 1 in accordance with the exemplary embodiments of Figures 1 to 3 and 6. The proposed method for the synthesis of methanol 1 will be described below, firstly with the aid of the proposed plant for the synthesis of methanol 1 from Figure 1. In principle, the exemplary embodiments of Figures 2, 3 and 6 are based on the exemplary embodiment of Figure 1; any differences that exist shall be pointed out.

[0017] In the proposed method for the synthesis of methanol 1, a first fresh gas flow comprising hydrogen and carbon oxides is obtained from a carbonaceous energy carrier flow 4 by steam reforming in a steam reformer 3. The carbonaceous energy carrier flow 4 in this case and preferably is a flow of natural gas comprising methane, ethane and propane.

[0018] In the proposed method for the synthesis of methanol 1, furthermore, a second fresh gas flow 5 comprising hydrogen and carbon oxides is obtained from the carbonaceous energy carrier flow 4 by partial oxidation in a POX reactor 6. In principle, in the case of this partial oxidation, this may be both catalytic partial oxidation as well as thermal partial oxidation. In contrast to catalytic partial oxidation, this thermal partial oxidation can also be described as non-catalytic partial oxidation. In the present case and preferably, the POX reactor 6 is used for thermal partial oxidation.

[0019] In addition, in the case of the proposed method for the synthesis of methanol 1, the first fresh gas flow 2 is fed to a first methanol reactor stage 7 for the synthesis of methanol 1. The proposed method for the synthesis of methanol 1 is characterized in that the second fresh gas flow 5 is fed to a second methanol reactor stage 8 for the synthesis of methanol 1.

[0020] As can be seen in Figures 1 to 3 and 6, and preferably, a first crude methanol flow 10 is obtained from a first condensing device 9 of the first methanol reactor stage 7 and is supplied to a first distillation assembly 11 in order to obtain a first methanol product flow 12 comprising methanol 1. Correspondingly, a second crude methanol flow 14 is obtained, preferably from a second condensing device 13 of the second methanol reactor stage 8, which is supplied to a second distillation assembly 15 in order to obtain a second methanol product flow 16 comprising methanol 1.

[0021] Preferably, the steam reformer 3 is heated by means of a fired heating device 17. This fired heating device 17 is comprised in the plant for the synthesis of methanol 1. Preferably, the fired heating device 17 is fed by the carbonaceous energy carrier flow 4. The heat required for the endothermic reforming reaction can be provided by the fired heating device 17.

[0022] In addition to the carbonaceous energy carrier flow 4, as an alternative or in addition, other sources for fuelling the fired heating device 17 may also be provided. These will be described in more detail below.

[0023] As already established above, the first fresh gas flow 2 for the synthesis of methanol has an excess of hydrogen, so that even after passing through the first methanol reactor stage 7, a surplus of hydrogen remains in the residual gas. This is exactly the opposite for the second fresh gas flow 5 and the residual gas from the second methanol reactor stage 8.

[0024] Correspondingly, the proposed method is further characterized in that a residual gas flow 18 comprising unreacted hydrogen and unreacted carbon oxides is obtained from the first methanol reactor stage 7 and in that at least a portion of the unreacted hydrogen is supplied to the second methanol reactor stage 8 for the synthesis of methanol. This situation is also shown in Figures 1 to 3 and 6. It may also be the case that substantially the entirety of the unreacted hydrogen of the residual gas flow 18 is supplied to the second methanol reactor stage 8 for the synthesis of methanol.

[0025] The residual gas flow 18 may in particular be obtained from the first condensing device 9 of the first methanol reactor stage 7. The supply of the above portion of the unreacted hydrogen may in this regard be carried out in different manners, and in particular both directly as well as indirectly.

[0026] In principle, it is sufficient if only the unreacted hydrogen of the residual gas flow 18 - i.e. without the further components of the residual gas flow

18 - is sent, at least in part, to the second methanol reactor stage 8. Preferably, at least a portion of the unreacted carbon oxides of the residual gas flow 18 is supplied to the second methanol reactor stage 8 for the synthesis of methanol 1.

[0027] A first preferred variation, which corresponds to the exemplary embodiments of Figures 1 and 3, is characterized in that a first partial flow 19 of the residual gas flow 18 is fed to the second methanol reactor stage 8 for the synthesis of methanol. Thus, in this case, the first partial flow 19 is fed to the second fresh gas flow 5, wherein this, as shown here and as preferably, is carried out operationally downstream of a pressure boost to the second fresh gas flow 5, as will be described in more detail below. Thus, as already mentioned above, in this case, a portion of the total residual gas flow 18, and therefore also a portion of the unreacted carbon oxides of the residual gas flow 18, is fed to the second methanol reactor stage 8. It is conceivable for the first partial flow 19 to be supplied to the second methanol reactor stage 8 in a pressure-boosted manner, wherein this variation is implemented in the exemplary embodiment of Figure 3. In the exemplary embodiment of Figure 1, the pressure in the first methanol reactor stage 7 is almost 20 bar higher than the pressure in the second methanol reactor stage 8, so that the first partial flow 19 has a sufficiently high pressure even after passing through the first condensing device.

[0028] In as much as a partial flow of a specific flow is discussed here and below, the partial flow may also be the entirety of the specific flow. The proviso is that there are no other partial flows of the specific flow. Correspondingly, in a preferred variation in accordance with the respective representation in Figures

1 and 3, substantially the entire first partial flow 19, in particular with a substantially uniform composition, is supplied to the second methanol reactor stage 8 for the synthesis of methanol 1. The substantially uniform composition of the first partial flow 19 means that this first partial flow 19 or its components do not undergo any substantial reaction prior to being supplied to the second methanol reactor stage 8. An example of a variation in the composition is given in the variation described below.

[0029] A second preferred variation for supplying at least a portion of the unreacted hydrogen of the residual gas flow 18 as well as here also a portion of the unreacted carbon oxides is shown in the second exemplary embodiment of Figure 2. This variation is characterized in that the first partial flow 19 of the residual gas flow 18 is supplied to the POX reactor 6 in order to obtain the second fresh gas flow 5. Specifically, this supply may be carried out indirectly, and in fact, the first partial flow 19 is supplied to the carbonaceous energy carrier flow prior to being supplied to the POX reactor 6. A supply to the POX reactor 6 does not affect the reaction in the POX reactor 6, because hydrogen and carbon oxides are in any case the educts of the partial oxidation in the POX reactor 6.

[0030] A third preferred variation for supplying at least a portion of the unreacted hydrogen of the residual gas flow 18 is shown in the fourth exemplary embodiment of Figure 6. In accordance with this variation, preferably, a first partial flow 19 of the residual gas flow 18 is supplied to a hydrogen recovery stage 52 in order to obtain a hydrogen-containing flow 53 and a residual flow 54. In accordance with the variation shown in Figure 6 and preferably, the hydrogen-containing flow 53 is supplied to the second methanol reactor stage 8 for the synthesis of methanol 1. However, it is also possible for the hydrogen-containing flow 53 to be supplied to the POX reactor 6 in order to obtain the second fresh gas flow 5. In respect of the residual flow 54, it is preferably supplied to the fired heating device 17 in order to feed it. This is also shown in Figure 6.

[0031] In principle, the hydrogen recovery stage 52 may obtain the hydrogen-containing flow 53 in any manner. Basically, the hydrogen-containing flow 53 may have any proportion of hydrogen. Preferably, the hydrogen-containing flow 53 may have a higher molar proportion of hydrogen than the residual gas flow 18. However, it may also be the case that the hydrogen-containing flow 53 substantially consists of hydrogen. The residual flow 54 is preferably a flow which is enriched in methane, carbon monoxide and/or carbon dioxide compared with the residual gas flow 18.

[0032] As can be seen in the exemplary embodiment of Figure 6, the hydrogen recovery stage 52 may comprise a pressure swing adsorption device (PSA) 55 in order to obtain the hydrogen-containing flow 53. Because of the high purity which is then obtained, the hydrogen-containing flow is in fact a flow of hydrogen 56. Specifically, the hydrogen-containing flow 53 is obtained on a high pressure side of the hydrogen recovery stage 52. Correspondingly, the residual flow 54 is obtained on a low pressure side of the hydrogen recovery stage 52. This configuration firstly has the advantage that methane in the first partial flow 19 is practically entirely removed from the circuit for methanol synthesis. Secondly, the high degree of purity obtained for the hydrogen may be particularly suitable for the desired adjustment of the stoichiometry. Finally, the hydrogen-containing flow 53 is obtained with a comparatively small pressure drop.

[0033] The hydrogen recovery stage 52 may, however, also comprise a membrane assembly or another device for obtaining the hydrogen-containing flow 53.

[0034] In addition to the aforementioned first partial flow 19 of the residual gas flow 18, other partial flows of the residual gas flow 18 may be provided. Preferably, a second partial flow 20 of the residual gas flow 18 is fed back to the first methanol reactor stage 7 for the synthesis of methanol 1. In accordance with the representation shown in Figures 1, 2 and 6, this feedback may be carried out by combining the second partial flow 20 with the first fresh gas flow 2. Preferably, this feedback of the second partial flow 20 of the residual gas flow 18 is carried out in a pressure-boosted manner. As is also shown in Figures 1, 2 and 6, this pressure boost may be carried out by a circulating compressor 21 which is comprised in the plant for the synthesis of methanol 1, which boosts the pressure of both the second partial flow 20 of the residual gas flow 18 as well as the first fresh gas flow 2 after they have been combined.

[0035] It is also conceivable for the circulation compressor 21 to be provided in order to boost the pressure of the second partial flow 20 of the residual gas flow 18 prior to being combined with the first fresh gas flow 2. Such a disposition is shown in the exemplary embodiment of Figure 3.

[0036] A possibility for removing methane which has not been reacted in the steam reformer from the methanol synthesis circuit consists in using a portion of the residual gas flow 18 to supply to the fired heating device 17. In this regard, preferably, a third partial flow 22 of the residual gas flow 18 is obtained from the residual gas flow 18. This third partial flow 22 of the residual gas flow 18 can then be supplied to the fired heating device 17 in order to feed the fired heating device 17. In this manner, upgrading and conversion of the methane into carbon dioxide takes place in the third partial flow 22. Removing from the circuit that methane which was supplied by the first partial flow 19 to the second methanol reactor stage 8 will be described below.

[0037] In principle, splitting of the residual gas flow 18 into the quantitative proportions may be carried out in any manner. However, preferably, a mass throughput of the third partial flow 22 is lower than a mass throughput of the first partial flow 19. In this regard, the mass throughput may in particular be given by the variable mass per unit time and in particular by the unit kilogram per minute or tonnes per hour. Specifically, the mass throughput of the third partial flow 22 is preferably between 25% and 70% of the mass throughput of the first partial flow 19. More precisely, the mass throughput of the third partial flow 22 may be between 40% and 50% of the mass throughput of the first partial flow 19. In the exemplary embodiment of Figure 1, the ratio of the mass throughput of the third partial flow 22 to the mass throughput of the first partial flow 19 is 30 to 70. It has been shown that a splitting ratio of this type implements both a suitable adjustment of the stoichiometry for the methanol synthesis and also an efficient operation of the fired heating device 17.

[0038] The recirculation of unreacted residual gas as described above for the first methanol reactor stage 7 by the second partial flow 20 of the residual gas flow 18 may also be provided for the second methanol reactor stage 8. Accordingly, in accordance with the representations in Figures 1 to 3 as well as 6, a further residual gas flow 23 comprising unreacted hydrogen and unreacted carbon oxides is obtained from the second methanol reactor stage 8 and a first partial flow 24 of the further residual gas flow 23 is fed back to the second methanol reactor stage 8 for the synthesis of methanol 1, in particular in a pressure-boosted manner. In the exemplary embodiment of Figure 3, the first partial flow 24 corresponds to the entirety of the further residual gas flow 23. Preferably, this feedback is carried in a pressure-boosted manner. In this regard, in accordance with the exemplary embodiments of Figures 1, 2 and 6, a recycle compressor 25 for boosting the pressure of the first partial flow 24 of the further residual gas flow 23 and which is comprised in the plant for the synthesis of methanol 1 may be provided.

[0039] In analogous manner to that for the residual gas flow 18, additional partial flows may also be provided for the further residual gas flow 23. In accordance with the representation of Figures 1 to 3 as well as 6, preferably, a second partial flow 26 of the further residual gas flow 23 is obtained. In this regard, as shown in Figures 1 to 3 and 6, this second partial flow 26 may be obtained operationally upstream of a pressure boost of the further residual gas flow 23 or of the first partial flow 24 of the further residual gas flow 23. In other words, the second partial flow 26 does not undergo this pressure boost, whereupon the corresponding device for boosting the pressure, here specifically the recycle compressor 25, is relieved of this throughput. Preferably, the second partial flow 26 of the further residual gas flow 23 is supplied to the fired heating device 17 in order to feed said fired heating device 17. In this manner, any remaining methane can be removed from the synthesis circuit for the second methanol reactor stage 8.

[0040] As a rule, fresh synthesis gas is obtained at a pressure which is not sufficient for the methanol synthesis, or in any case is not sufficient for an economic operation of the methanol synthesis. Thus, preferably, the first fresh gas flow (2) is pressure-boosted by a first synthesis gas compressor 27 before being supplied to the first methanol reactor stage 7 and the second fresh gas flow 5 is pressure-boosted by a second synthesis gas compressor 28 before being supplied to the second methanol reactor stage 8. The first synthesis gas compressor 27 and the second synthesis gas compressor 28 are respectively comprised in the plant for the synthesis of methanol 1. Both the first synthesis gas compressor 27 and also the second synthesis gas compressor 28 may each have a plurality of compressor stages. In a preferred variation, the first partial flow 19 of the residual gas flow 18 is supplied to the second fresh gas flow 5, wherein this is preferably carried out operationally downstream of the second synthesis gas compressor 28. In this manner, the second synthesis gas compressor 28 is relieved of load. In a further preferred variation, the second synthesis gas compressor 28 has a plurality of compressor stages and the first partial flow 19 is supplied to the second fresh gas flow 5 operationally between two compressor stages of the plurality of compressor stages.

[0041] In principle, the POX reactor 6 may also be operated with ambient air. In a preferred embodiment as shown in Figures 1 to 3 and 6, an O_2 flow 29 substantially consisting of oxygen is supplied to the POX reactor 6 from an air separation device 30 in order to obtain a nitrogen flow 31. In principle, the nitrogen flow 31 may be put to any use. The use of an O_2 flow 29 which substantially consists of oxygen for the POX reactor 6 results, inter alia, in the second fresh gas flow 5 having only a little nitrogen, that nitrogen being inert for the synthesis of methanol. Avoiding having this nitrogen in the second fresh gas flow 5 means that the dimensions of the compressors as well as that of the second synthesis gas compressor 28 can be reduced.

[0042] In principle, both the first methanol reactor stage 7 as well as the second methanol reactor stage 8 can be configured in any manner. Preferably, firstly, the first methanol reactor stage 7 has an adiabatic quench reactor 32 for the synthesis of methanol 1, as shown in more detail in Figure 4,. The quench reactor 32 has a plurality of infeed openings 33a-d which are spaced apart from one another for supplying the first fresh gas flow 2. Similarly, the quench reactor has a plurality of catalyst beds 34a-d which are spaced apart from one another for the synthesis of methanol 1. Both the infeed openings 33a-d and the catalyst beds 34a-d are preferably separated along a flow path 35 of the first fresh gas flow 2 through the quench reactor 32. By means of this type of arrangement, the temperature rise due to the exothermic methanol synthesis reaction in the quench reactor 32 can be limited. Such a quench reactor 32 is advantageously suitable when the stoichiometry for the synthesis of methanol in the reactor is somewhat unfavourable, because otherwise, despite the subdivision of the catalyst beds 34a-d, the temperature rise might not be sufficiently limited and as a result, the catalyst would be compromised. In this regard, the quench reactor 32 is then useful if essentially, the over-stoichiometric synthesis gas from a steam reformer is to be used for the methanol synthesis.

[0043] In this context, it is secondly preferable for the second methanol reactor stage 8 to have an isothermal reactor 36 as shown in Figure 5. The isothermal reactor 36 has just one single supply opening 37 for supplying the second fresh gas flow 5. Furthermore, in the isothermal reactor 36, the heat of reaction of the methanol synthesis generated in the catalyst bed of the isothermal reactor 36 is dissipated into a water bath. Medium pressure steam 38 is obtained thereby and discharged. As a result, the overall temperature in the catalyst bed of the isothermal reactor 36 essentially corresponds to the boiling temperature at the pressure of the cooling water 39.

[0044] In principle, the proposed plant for the synthesis of methanol and the proposed method for the synthesis of methanol may consist of just one steam reformer 3 and only one POX reactor 6 with the respective corresponding methanol reactor stage 7, 8, which corresponds to the exemplary embodiments of Figures 1, 2 and 6. Preferably, however, more than one steam reformer 3 and correspondingly too, more than two methanol reactor stages 7, 8 are provided. Figure 3 shows such an exemplary embodiment.

[0045] A corresponding preferred embodiment is characterized in that at least one further fresh gas flow 40 comprising hydrogen and carbon oxides is obtained from the carbonaceous energy carrier flow 4 in at least one further steam reformer 41 by steam reforming, the at least one further fresh gas flow 40 is supplied to at least one further methanol reactor stage 42 for the synthesis of methanol 1, a respective further residual gas flow 43 comprising unreacted hydrogen and unreacted carbon oxides is obtained from the at least one further methanol reactor stage 42, and at least a portion of the unreacted hydrogen and the unreacted carbon oxides of the further residual gas flow 43 in each case is supplied to the second methanol reactor stage 8 for the synthesis of methanol 1. The exemplary embodiment of Figure 3 shows a plant for the synthesis of methanol 1 which has exactly one further steam reformer 41 and exactly one further methanol reactor stage 42 for the synthesis of methanol 1, so that respectively exactly one further fresh gas flow 40 and exactly one further residual gas flow 43 are obtained.

[0046] More preferably, the at least one further methanol reactor stage 43 respectively has one further condensing device 44 for obtaining a respective further crude methanol flow 45, which is supplied to a respective further distillation assembly 46 in order to obtain a respective further methanol product flow 47 comprising methanol 1.

[0047] A first partial flow 50 of the further residual gas flow 43 is preferably, and as shown in Figure 3, supplied to the second methanol reactor stage 8 for the synthesis of methanol 1. In contrast, a second partial flow 49 of the further residual gas flow 43 is fed back to the further methanol reactor stage 42.

[0048] The plant for the synthesis of methanol 1 of Figure 3 preferably additionally, and as shown for the second methanol reactor stage 8 and the further methanol reactor stage 42, has a respective circulation compressor 21 or a further circulation compressor 48. In this regard, the further circulation compressor 48 is configured to boost the pressure of the second partial flow 49 of the further residual gas flow 43.

[0049] Furthermore, the plant for the synthesis of methanol 1 of Figure 3, as shown and also preferably, has a collective compressor 51 which boosts the pressure of both the first partial flow 19 of the residual gas flow 18 as well as the first partial flow 50 of the further residual gas flow 43 after they have been combined. After combining and pressure-boosting, the first partial flow 19 of the residual gas flow 18 and the first partial flow 50 of the further residual gas flow 43 are preferably combined with the second fresh gas flow 5.

[0050] The proposed method for converting a plant for the synthesis of methanol 1, which plant comprises at least one steam reformer 3, 41 for obtaining a respective fresh gas flow 2, 5, 40 comprising hydrogen and carbon oxides by steam reforming from a carbonaceous energy carrier flow 4 and at least one methanol reactor stage 7, 8 for the synthesis of methanol 1 from a respective fresh gas flow 2, 5, 40, is characterized in that a POX reactor 6 for obtaining a fresh gas flow 2, 5, 40 is added to the plant.

[0051] As just established, the plant may have exactly one steam reformer 3,41 and exactly one methanol reactor stage 7, 8. However, preferably, the plant has a plurality of steam reformers 3, 41 for obtaining a respective fresh gas flow 2, 5, 40 with water and carbon oxides by steam reforming from a carbonaceous energy carrier flow 4 and a plurality of methanol reactor stages 7, 8 for the synthesis of methanol 1 from a respective fresh gas flow 2, 5, 40.

[0052] This addition of the POX reactor 6 may be carried out in different manners in this case. In a first preferred variation, in which the plant has a plurality of steam reformers 3, 41 and a plurality of methanol reactor stages 7, 8, one steam reformer 3, 41 of the plurality of steam reformers 3, 41 is replaced by a POX reactor 6 for obtaining the respective fresh gas flow 2, 5, 40.

[0053] In principle, the methanol reactor stage 7, 8 may be retained here in the strand of the replaced steam reformer 3, 41. However, preferably, in addition, another methanol reactor stage 7, 8 of the plurality of methanol reactor stages 7, 8 is also replaced by another methanol reactor stage 7, 8. This other methanol reactor stage 7, 8 may in particular comprise an isothermal reactor 36 somewhat as shown in Figure 5.

[0054] Advantageously, compressors of the plant are retained when the POX reactor 6 is added. In particular, it is preferable for the circulation compressor 21, the recycle compressor 25, the first synthesis gas compressor 27, the second synthesis gas compressor 28 and/or the further circulation compressor 48 to be retained.

[0055] Instead of replacing a steam reformer 3, 41 within an existing strand, the "addition of the POX reactor 6" may also signify adding a new strand. Thus, in a preferred variation, yet another methanol reactor stage 7, 8 for the synthesis of methanol 1 is added to the plant and the fresh gas flow 2, 5, 40 which is obtained from the POX reactor 6 is supplied to the added further methanol reactor stage 7, 8.

[0056] In accordance with a preferred variation of the method for the conversion of a plant for the synthesis of methanol 1, the at least one steam reformer 3, 41 for obtaining a respective fresh gas flow 2, 5, 40 comprising hydrogen and carbon oxides and the at least one methanol reactor stage 7, 8 for the synthesis of methanol 1 are substantially operated further during the addition of the POX reactor 6. This means that the operation of the at least one steam reformer 3, 41 and the at least one methanol reactor stage 7, 8 only has to be adapted or stopped when the POX reactor 6 itself starts to operate and becomes an active component of the plant. This possibility in particular concerns the variation in which, along with the POX reactor 6, the further methanol reactor stage 7, 8 for the synthesis of methanol 1 is added to the plant and the fresh gas flow 2, 5, 40 obtained from the POX reactor 6 is supplied to the added further methanol reactor stage 7, 8.

[0057] The plant for the synthesis of methanol 1 of Figures 1 to 3 and 6 may respectively be understood to be the result of the proposed method for the conversion of a plant for the synthesis of methanol 1. Specifically, the POX reactor 6 and the second methanol reactor stage 8, which has an isothermal reactor 36, replace a previously provided steam reformer and a previously provided methanol reactor stage with a quench reactor.

[0058] The proposed plant for the synthesis of methanol 1 comprises a steam reformer 3 for obtaining a first fresh gas flow 2 comprising hydrogen and carbon oxides from a carbonaceous energy carrier flow 4. In addition, the proposed plant for the synthesis of methanol 1 has a POX reactor 6 for obtaining a second fresh gas flow 5 comprising hydrogen and carbon oxides from the carbonaceous energy carrier flow 4 by means of partial oxidation. The proposed plant for the synthesis of methanol 1 furthermore has a first methanol reactor stage 7 for the synthesis of methanol 1 from the first fresh gas flow 2.

[0059] The proposed plant for the synthesis of methanol 1 is characterized in that the plant comprises a second methanol reactor stage 8 for the synthesis of methanol 1 from the second fresh gas flow 5.

[0060] The proposed plant for the synthesis of methanol 1 is further characterized in that a residual gas flow 18 comprising unreacted hydrogen and unreacted carbon oxides is obtained from the first methanol reactor stage 7 and in that at least a portion of the unreacted hydrogen of the residual gas flow 18 is supplied to the second methanol reactor stage 8 for the synthesis of methanol 1.

Patentkrav

1. Fremgangsmåde til syntese af metanol (1), hvor en første frisk gasstrøm (2) med hydrogen og carbonoxider udvindes fra en carbonholdig energibærestrøm (4) ved dampreformering i en dampreformer (3), hvor en anden frisk gasstrøm (5) med hydrogen og carbonoxider udvindes fra en carbonholdig energibærestrøm (4) ved partiel oxidation i en POX-reaktor (6), hvor den første friske gasstrøm (2) tilføres en første metanolreaktorindretning (7) til syntese af metanol (1), **kendetegnet ved, at** den anden friske gasstrøm (5) tilføres en anden metanolreaktorindretning (8) til syntese af metanol (1), at der udvindes en restgasstrøm (18) med ureageret hydrogen og ureagerede carbonoxider fra den første metanolreaktorindretning (7), og at mindst en del af det ureagerede hydrogen i restgasstrømmen (18) tilføres den anden metanolreaktorindretning (8) til syntese af metanol (1).

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** dampreformeren (3) opvarmes via en fyret varmeanordning (17), foretrukket, at den fyrede varmeanordning (17) forsynes af den carbonholdige energiebærestrøm (4).

3. Fremgangsmåde ifølge krav 1 eller 2, **kendetegnet ved, at** også i det mindste en del af de ureagerede carbonoxider i restgasstrømmen (18) tilføres den anden metanolreaktorindretning (8) til syntese af metanol (1).

4. Fremgangsmåde ifølge et af kravene 1 til 3, **kendetegnet ved, at** en første delstrøm (19) af restgasstrømmen (18), særligt trykforøget, tilføres den anden metanolreaktorindretning (8) til syntese af metanol (1), foretrukket, at i det væsentlige hele den første delstrøm (19), særligt med i det væsentlige konstant sammensætning, tilføres den anden metanolreaktorindretning (8) til syntese af metanol (1).

5. Fremgangsmåde ifølge et af kravene 1 til 3, **kendetegnet ved, at** en første delstrøm (19) af restgasstrømmen (18) tilføres POX-reaktoren (6) til udvinding af den anden friske gasstrøm (5).

6. Fremgangsmåde ifølge et af kravene 1 til 3, **kendetegnet ved, at** en første delstrøm (19) af restgasstrømmen (18) tilføres en hydrogengenindvindingsindretning (52) til udvinding af en hydrogenholdig strøm (53) og en reststrøm (54), foretrukket, at den hydrogenholdige strøm (53) tilføres den anden metanolreaktorindretning (8) til syntese af metanol (1), særligt, at den hydrogenholdige strøm (53) i det væsentlige består af hydrogen.

7. Fremgangsmåde ifølge et af kravene 1 til 6, at en anden delstrøm (20) af restgasstrømmen (18) yderligere foretrukket føres trykforøget tilbage til den første metanolreaktorindretning (7) til syntese af metanol (1).

8. Fremgangsmåde ifølge et af kravene 1 til 7, **kendetegnet ved, at** en tredje delstrøm (22) af restgasstrømmen (18) udvindes fra restgasstrømmen (18), yderligere foretrukket, at den tredje delstrøm (22) af restgasstrømmen (18) tilføres den fyrede varmeanordning (17) til forsyning af den fyrede varmeanordning (17).

9. Fremgangsmåde ifølge krav 8, **kendetegnet ved, at** en flowrate af den tredje delstrøm (22) er lavere end en flowrate af den første delstrøm (19), foretrukket, at flowraten af den tredje delstrøm (22) udgør mellem 25 % og 70 % af flowraten af den første delstrøm (19), særligt, at flowraten af den tredje delstrøm (22) udgør mellem 40 % og 50 % af flowraten af den første delstrøm (19).

10. Fremgangsmåde ifølge et af kravene 1 til 9, **kendetegnet ved, at** en yderligere restgasstrøm (23) med ureageret hydrogen og ureagerede carbonoxider udvindes fra den anden metanolreaktorindretning (8), og at en første delstrøm (24) af den yderligere restgasstrøm (23) særligt trykforøget tilføres den anden metanolreaktorindretning (8) til syntese af metanol (1).

11. Fremgangsmåde ifølge krav 10, **kendetegnet ved, at** der udvindes en anden delstrøm (26) af den yderligere restgasstrøm (23), foretrukket procesteknisk placeret før en trykforøgelse af den yderligere restgasstrøm (23), foretrukket, at den anden delstrøm (26) af den yderligere restgasstrøm (23) tilføres den fyrede varmeanordning (17) til forsyning af den fyrede varmeanordning (17).

12. Fremgangsmåde ifølge et af kravene 1 til 11, **kendetegnet ved, at** den første friske gasstrøm (2) trykforøges via en første syntesegaskompressor (27), før den tilføres den første metanolreaktorindretning (7), og at den anden friske gasstrøm (5) trykforøges via en anden syntesegaskompressor (28), før den tilføres den anden metanolreaktorindretning (8), foretrukket, at den første delstrøm (19) af restgasstrømmen (18) tilføres til den anden friske gasstrøm (5).

13. Fremgangsmåde ifølge et af kravene 1 til 12, **kendetegnet ved, at** POX-reaktoren (6) tilføres en O2-strøm (29), der i det væsentlige består af oxygen, fra en luftseparationsanordning (30) til udvinding af en nitrogenstrøm (31).

14. Fremgangsmåde ifølge et af kravene 1 til 13, **kendetegnet ved, at** mindst en yderligere frisk gasstrøm (40) med hydrogen og carbonoxider udvindes fra en carbonholdig energibærestrøm (4) ved dampreformering i mindst en yderligere dampreformer (41), at den mindst ene yderligere friske gasstrøm (40) tilføres mindst en yderligere metanolreaktorindretning (42) til syntese af metanol (1), og at der udvindes en respektiv yderligere restgasstrøm (43) med ureageret hydrogen og ureagerede carbonoxider fra den mindst ene yderligere metanolreaktorindretning (42), og at i det mindste en del af det ureagerede hydrogen og de ureagerede carbonoxider i den respektive yderligere restgasstrøm (43) tilføres den anden metanolreaktorindretning (8) til syntese af metanol (1).

15. Fremgangsmåde til ombygning af et anlæg til syntese af metanol (1), hvilket anlæg har mindst en dampreformer (3, 41) til udvinding af en respektiv frisk gasstrøm (2, 5, 40) med hydrogen og carbonoxider ved dampreformering fra en carbonholdig energibærestrøm (4) og mindst en metanolreaktorindretning (7, 8) til syntese af metanol (1) fra en respektiv frisk gasstrøm (2, 5, 40), **kendetegnet ved, at** der tilføjes en POX-reaktor (6) til anlægget til udvinding af en frisk gasstrøm (2, 5, 40).

16. Fremgangsmåde til syntese af metanol (1) med en dampreformer (3) til udvinding af en første frisk gasstrøm (2) med hydrogen og carbonoxider ved dampreformering fra en carbonholdig energibærestrøm (4) med en POX-reaktor (6) til udvinding af en anden frisk gasstrøm (5) med hydrogen og carbonoxider ved partiel oxidation fra den carbonholdige energibærestrøm (4) og en første metanolreaktorindretning (7) til syntese af metanol (1) fra den første friske gasstrøm (2), **kendetegnet ved, at** anlægget har en anden metanolreaktorindretning (8) til syntese af metanol (1) fra den anden friske gasstrøm (5), at der udvindes en restgasstrøm (18) med ureageret hydrogen og ureagerede carbonoxider fra den første metanolreaktorindretning (7), og at i det mindste en del af det ureagerede hydrogen i restgasstrømmen (18) tilføres den anden metanolreaktorindretning (8) til syntese af metanol (1).

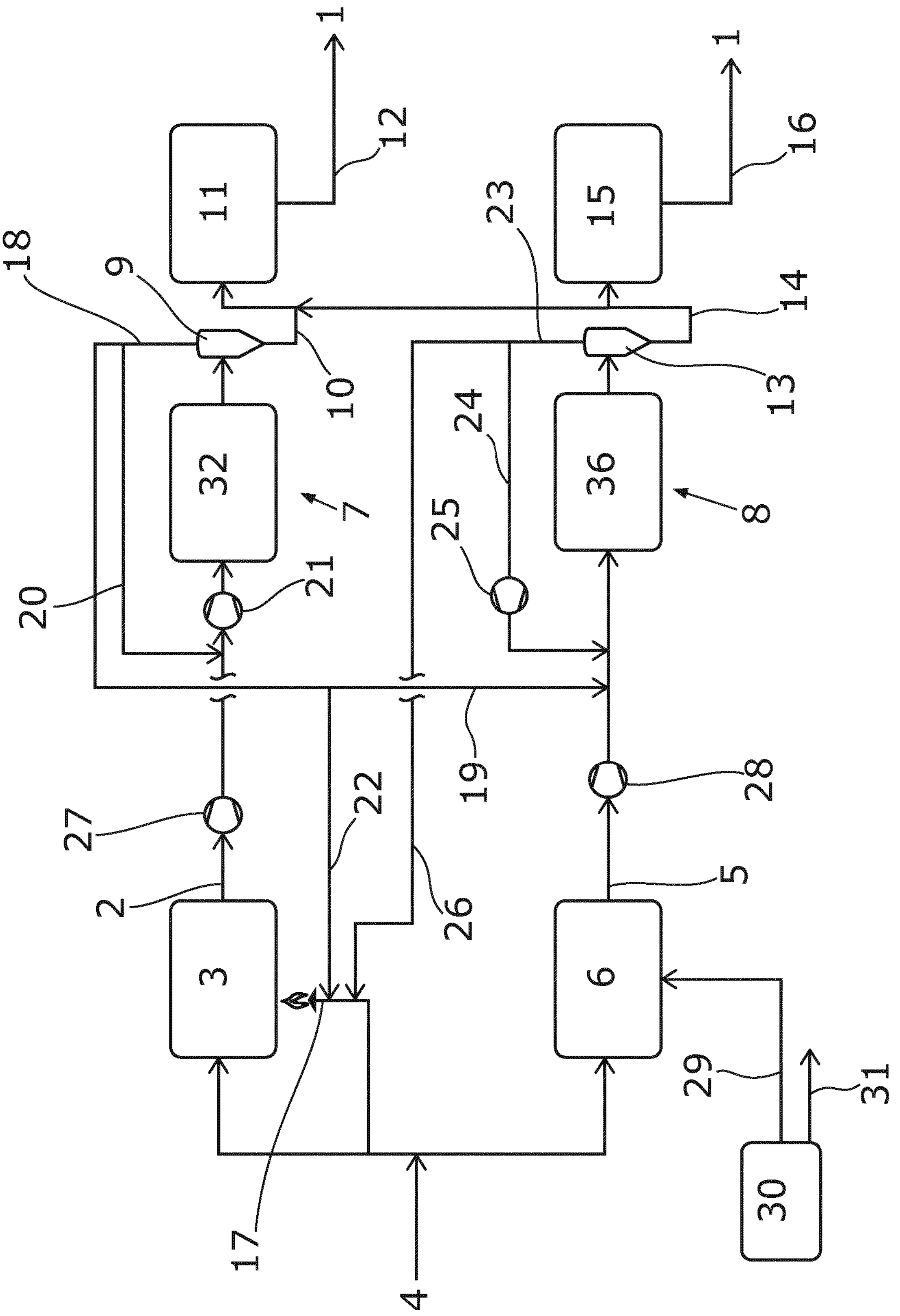
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Fig. 1

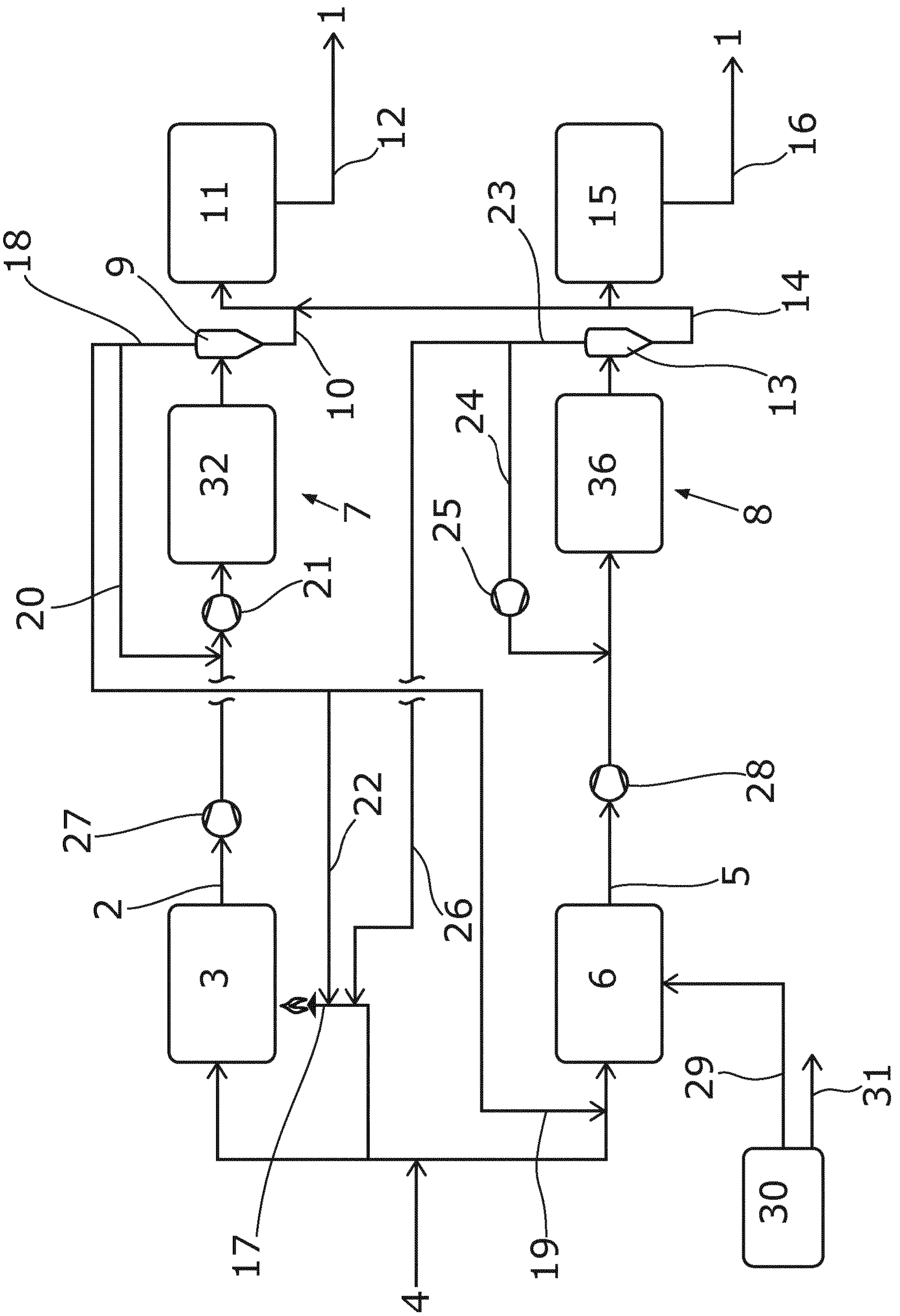
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Fig. 2

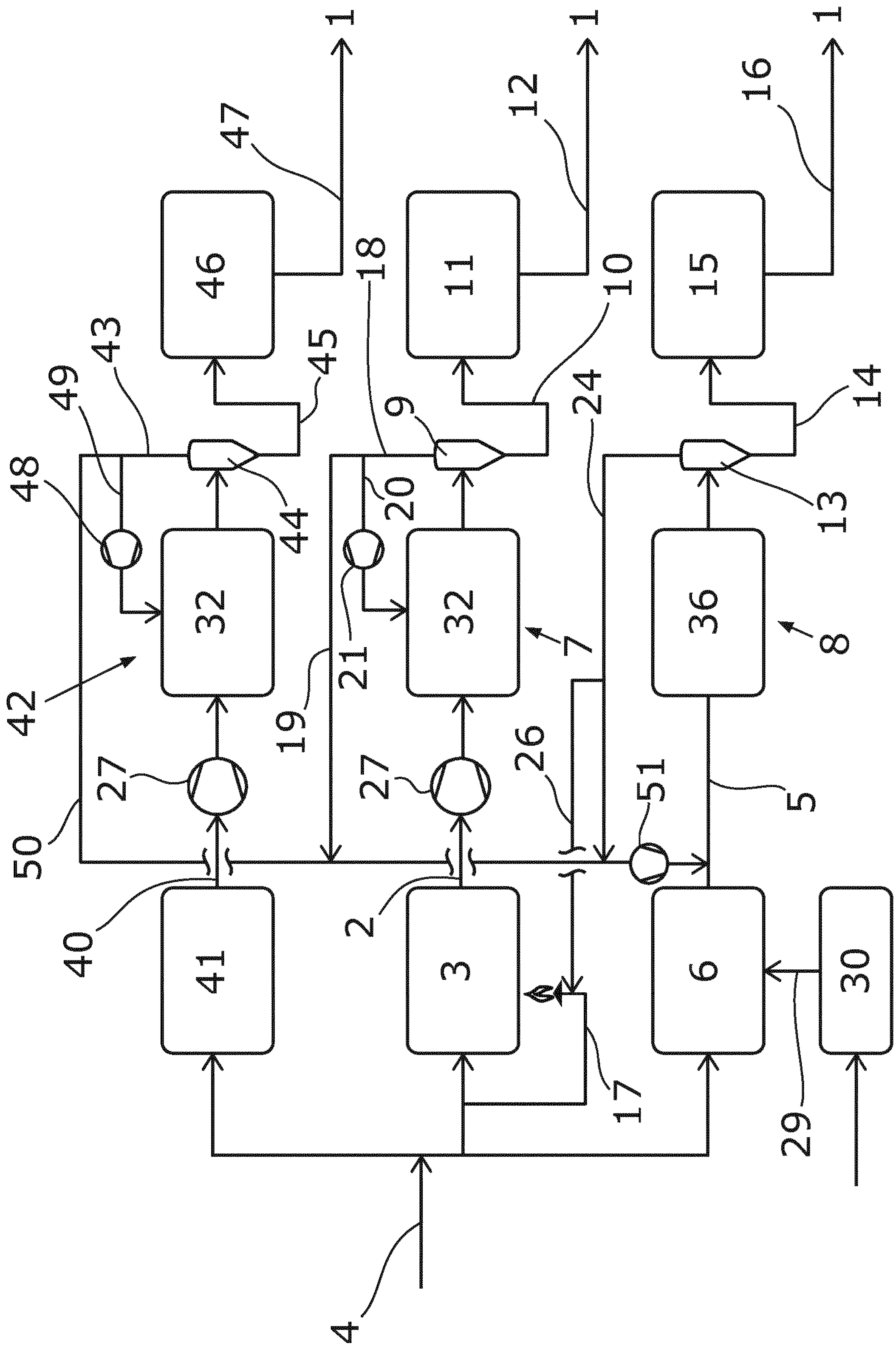
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Fig. 3

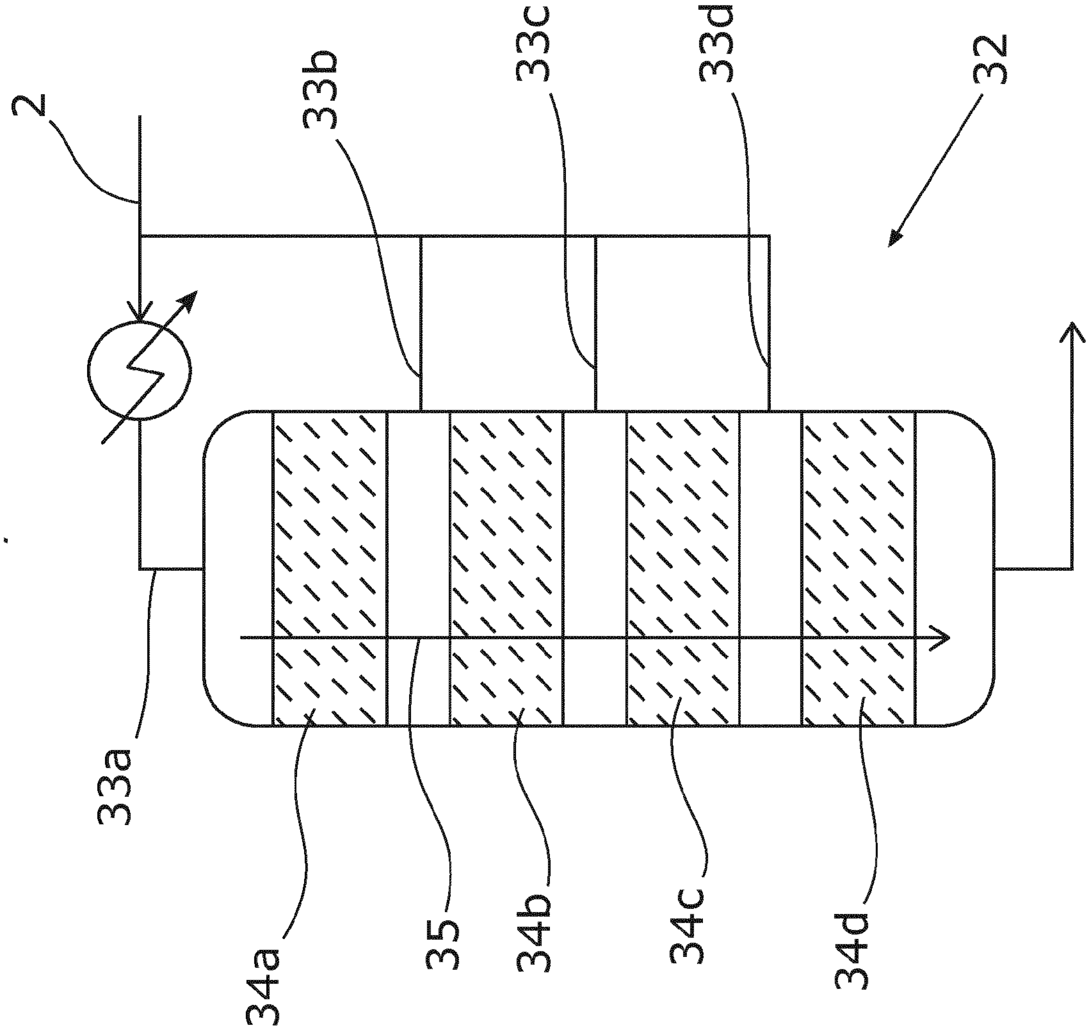

Fig. 4

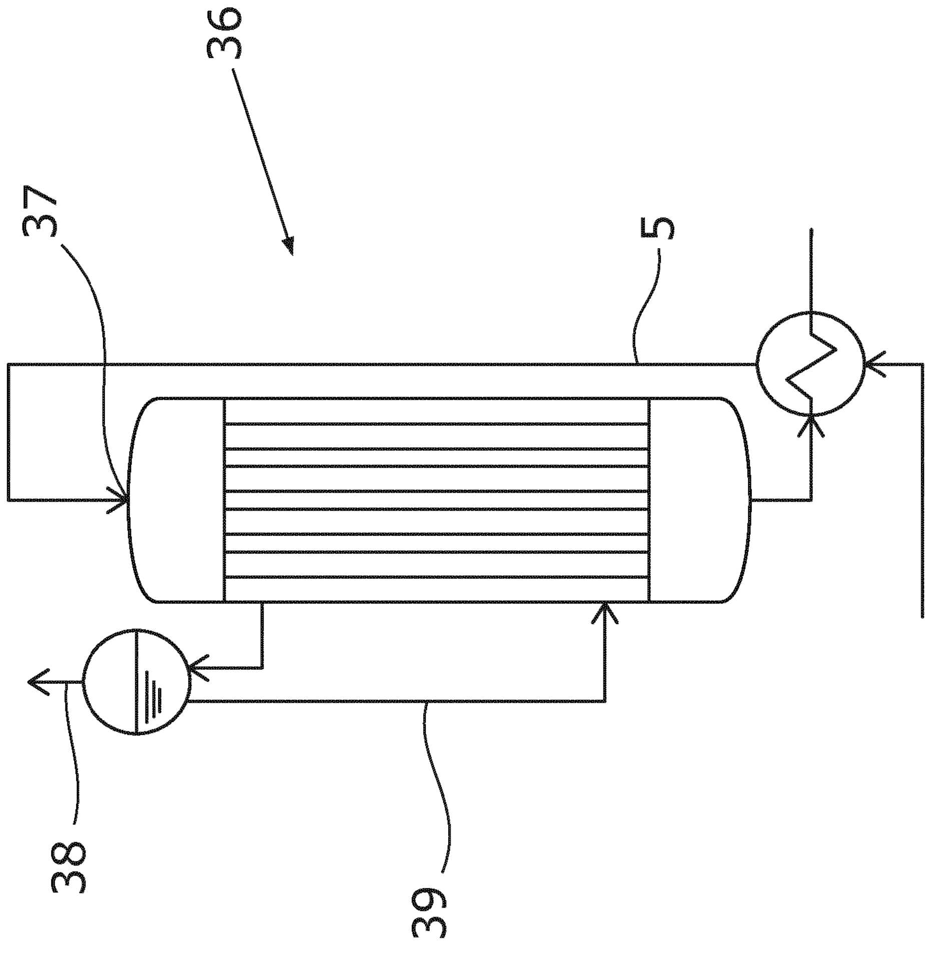

Fig. 5

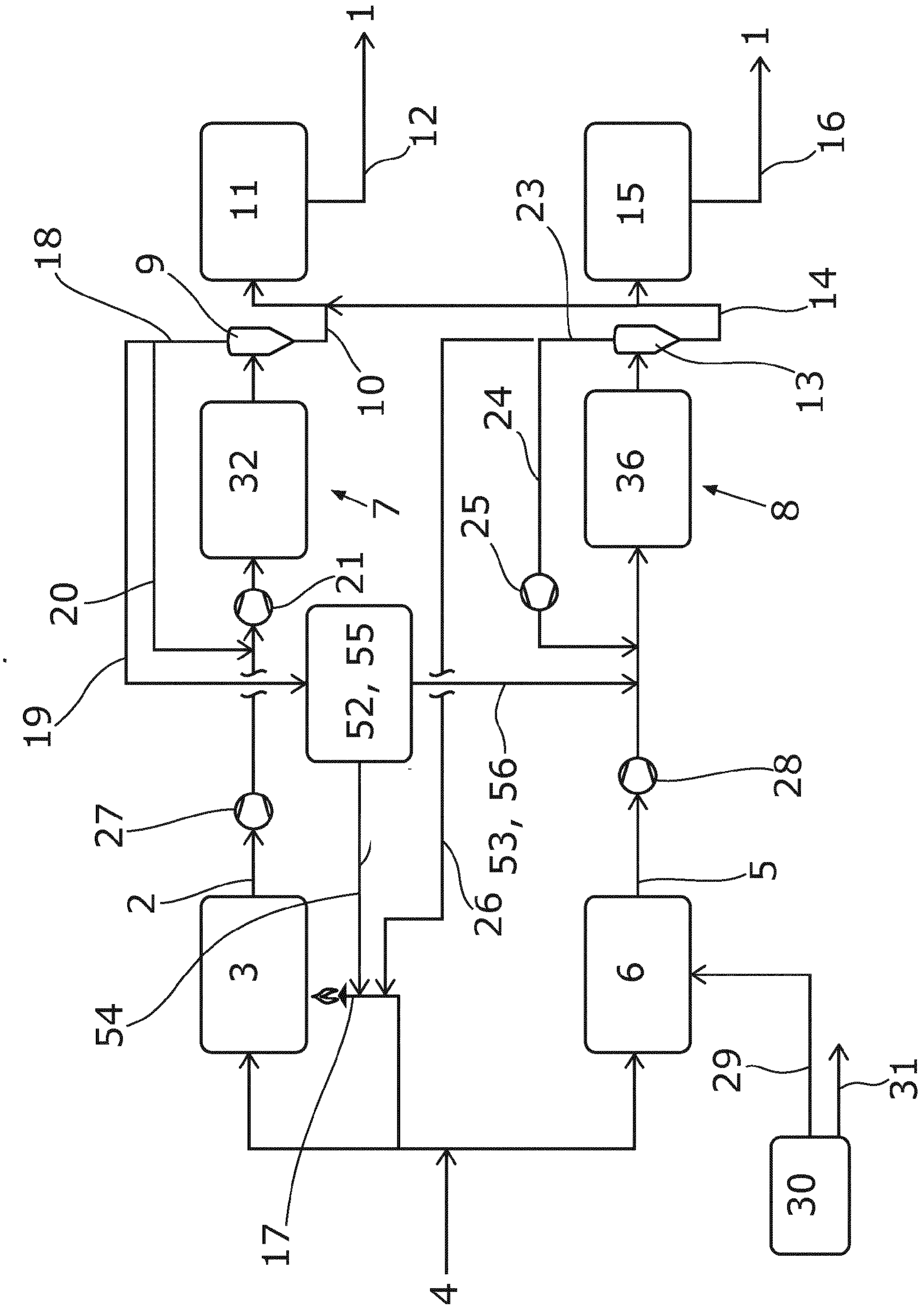
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Fig. 6