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(54) ELECTROLYSIS ARRANGEMENT AND METHOD

(57) Electrolysis arrangement (1) comprising:
- a pump unit (2),
- multiple stacks (3),
- a respective control valve (8) for each of the stacks (3),
- an anode separator (9), and
- a cathode separator (13).

Due to the control valves (8) assigned to each of the stacks (3) an independent flow control can be achieved for the stacks (3). This allows safe and reliable operation of the electrolysis arrangement (1), although multiple stacks (3) are connected to the same anode separator (9) and to the same cathode separator (13).

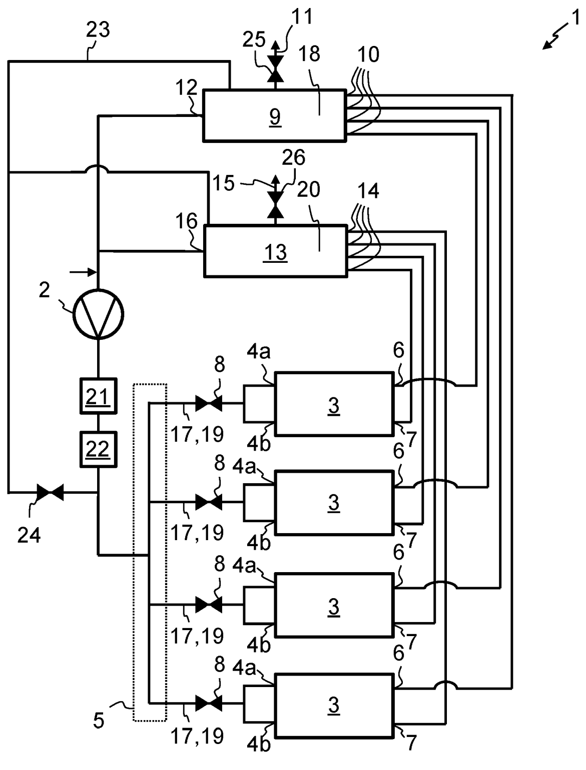

Fig. 1

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Description

[0001] The invention is directed to an electrolysis arrangement and a method for performing an electrolysis.

[0002] On an industrial scale, electrolysis is usually performed using stacks of electrolysis cells. Each of the electrolysis cells has an anode and a cathode, between which a voltage is applied. The medium that is the subject of the electrolysis is supplied to the electrolysis cells via a cathode inlet into a cathode space and via an anode inlet into an anode space. The anode space and the cathode space are separated from each other by a membrane. At anode and cathode outlets of the electrolysis stack the electrolysis products can be extracted from the electrolysis cells. However, the electrolysis products are mixed with the unreacted medium. Hence, separators are used to separate the electrolysis products from the medium.

[0003] The pressure differential across the membrane has a significant influence on the electrolysis. In particular, this is due to the fact that a pressure difference between the cathode space and the anode space drives the medium through the membrane. Hence, accurate pressure control is desired. The overall pressure is usually controlled by a pump that drives the medium. The pressure differential between the anode and cathode inlets of an electrolysis stack usually depends on a back pressure generated by the anode and cathode separators, respectively. In known electrolysis arrangements, therefore, each stack is provided with a respective anode separator and with a respective cathode separator. Having a respective anode separator and a respective cathode separator for each electrolysis stack is considered necessary in terms of reliability. However, such an arrangement is expensive. Not only are multiple anode separators and cathode separators required. Moreover, each of the electrolysis stacks is usually equipped with a respective cooler and filter, together with appropriate safety and control instrumentation. This is not only relevant in terms of an initial investment, but also in terms of maintenance costs dues to the large number of pieces of equipment.

[0004] The object of the invention is to improve the prior art such that electrolysis can be performed with simplified equipment.

[0005] The object is solved with an electrolysis arrangement and a method for performing electrolysis according to the independent claims. Advantageous refinements are presented in the dependent claims. The features described in the claims and in the description can be combined with each other in any technologically reasonable manner.

[0006] According to the invention an electrolysis arrangement is presented that comprises:

- at least one pump unit for driving a medium,
- multiple stacks of electrolysis cells, wherein each stack comprises a stack inlet that is connected to one of the pump units via a header for separating a flow of the medium provided by the respective pump unit into a respective flow for each of the stacks, and wherein each stack comprises a respective anode outlet and a respective cathode outlet, wherein the stacks are configured to obtain by electrolysis of the medium introduced into the respective stack inlet an anode product provided together with the medium at the respective anode outlet and a cathode product provided together with the medium at the respective cathode outlet,
- for each of the stacks a respective control valve arranged between the header and the respective stack inlet, wherein the control valves are configured to individually control a flow of the medium,
- an anode separator having an anode separator medium outlet that is connected to one of the pump units, wherein each of the anode outlets of the stacks is connected to a respective anode separator inlet of the anode separator, and wherein the anode separator is configured to separate the anode product from the medium introduced into the anode separator inlets such that the anode product is provided at an anode separator product outlet and the medium is provided at the anode separator medium outlet and,
- a cathode separator having a cathode separator medium outlet that is connected to one of the pump units, wherein each of the cathode outlets of the stacks is connected to a respective cathode separator inlet of the cathode separator, and wherein the cathode separator is configured to separate the cathode product from the medium introduced into the cathode separator inlets such that the cathode product is provided at a cathode separator product outlet and the medium is provided at the cathode separator medium outlet.

[0007] The electrolysis arrangement can be used for electrolysis of a medium. Instead of the term "electrolysis arrangement" also the term "electrolyser" could be used. Preferably, the medium is water. In that case hydrogen and oxygen can be obtained as electrolysis products. The electrolysis arrangement is intended to be used for an industrial scale electrolysis. For example, it is preferred that at least one of the electrolysis products is obtained at a rate of 250 to 1500 Nm^3 per hour per stack. This applies, in particular, to the production of hydrogen in the case of water electrolysis. The electrolysis is preferably performed in an automated way.

[0008] The electrolysis arrangement comprises multiple stacks. Preferably, the electrolysis arrangement comprises 2 to 16 stacks, in particular 2, 4 or 8 stacks. The stacks can also be referred to as electrolysis stacks. Each of the stacks comprises several electrolysis cells. Each stack has at least one stack inlet, an anode outlet and a cathode outlet. The medium can be provided to the stack via the stack inlet(s). Within the stack the electrolysis of the medium can be performed using the electrolysis cells. Thereby, an anode product and a cathode product are obtained. In the case of water as the medium the anode product is oxygen and the cathode product is hydrogen. The anode product can be extracted from the stack via the anode outlet. Thereby, however, the anode product will be mixed with the medium. Analogously, a mixture of the cathode product and the medium can be extracted from the stack via the cathode outlet.

[0009] Each of the electrolysis cells preferably comprises an anode, an anode space adjacent to the anode, a cathode and a cathode space adjacent to the cathode. The cathode space is preferably separated from the anode space by a membrane and, optionally also by the anode and the cathode. The anode outlet is preferably connected to the anode space. The cathode outlet is preferably connected to the cathode space. The membrane is preferably permeable for certain ions. For example, in the case of PEM electrolysis cells the membrane is preferably permeable for hydrogen ions (H^+). In that case the anode and the cathode are permeable and arranged adjacent to the membrane. Also in this case it is preferred that each stack has only one stack inlet, which is connected to the cathode space. As a further example, in the case of alkaline electrolysis cells, the membrane is preferably permeable for hydroxide ions (OH). In that case each of the stacks has preferably two stack inlets: a respective anode stack inlet and a respective cathode stack inlet. The anode stack inlet is preferably connected to the anode space. The cathode stack inlet is preferably connected to the cathode space.

[0010] The electrolysis arrangement further comprises an anode separator and a cathode separator. The following description applies to both the anode separator and the cathode separator. The separators are configured for separating the electrolysis products from the medium. The separators have a respective separator inlet, a respective separator product outlet and a respective separator medium outlet. If a mixture of the product and the medium is provided at the separator inlet, the mixture is separated within the separator such that only the majority of the medium (that is >99%) is provided at the separator medium outlet and only the majority of the product (that is >99%) is provided at the separator product outlet. The medium is preferably liquid, while the products are preferably gaseous. The separators are hence preferably configured as gas/liquid separators. The anode separator and the cathode separator are preferably not connected to each other except for indirect connections via the separator outlets and/or via the separator inlets.

[0011] The anode outlets of the stacks are connected to the anode separator inlets. That is, the anode outlets of all stacks are connected to the anode separator inlets of the same anode separator. Preferably, there is only one cathode separator. The cathode outlets of the stacks are connected to the cathode separator inlets. That is, the cathode outlets of all stacks are connected to the cathode separator inlets of the same cathode separator. Preferably, there is only one cathode separator.

[0012] The medium is driven by at least one pump unit. The at least one pump unit preferably has a variable flow. That is, the flow of the medium generated by the pump unit can be controlled, for example, by controlling the rotation speed of at least one pump of the at least one pump unit. In case there are multiple pump units, it is preferred that the flows of the medium generated by the pump units can be controlled independently of each other. The at least one pump unit can comprise one or more pumps. In the case of more than one pump, the pumps of a pump unit are configured such that one, some or all of the pumps of this pump unit can contribute to the flow generated by this pump unit. For example, a pump unit can have two pumps, of which one pump can be active, while the other pump is used as a backup. Alternatively, both pumps of the pump unit can be used simultaneously to avoid that one of the pumps has to be operated at its maximum power. It should be noted that the electrolysis arrangement can comprise multiple pump units, each comprising multiple pumps. To that end, the electrolysis arrangement can have, for example, four pumps, of which two form a first pump unit and the other two form a second pump unit.

[0013] In a first embodiment there is only one pump unit. In that case a pump unit outlet is connected to all stack inlets. This does not mean that the pump unit has to be connected directly to the stack inlets. In particular, a means for returning excess flow to the separators to balance the feed medium flow can be arranged in between the pump unit and the stack inlets. Between the pump unit and the stack inlets a header is provided for separating a flow of the medium provided by the pump unit into a respective flow of for each of the stacks. That is, by means of the header the flow of the medium is distributed to the stack inlets. Further, the anode separator medium outlet and the cathode separator medium outlet are connected to a pump unit inlet. This may be via an intermediate common vessel. This way, the medium can be circulated by the pump unit through the stacks and the separators. The first embodiment can be referred to as a single feed or as a common feed because the medium is fed to the stacks via only one feed line that is distributed to the stacks. In particular in this embodiment it is possible that each of the stacks has only one stack inlet. This is particularly preferred in the case of PEM electrolysis cells. Alternatively, each of the stacks can have a respective anode stack inlet and a respective cathode stack inlet. This is particularly preferred in the case of alkaline electrolysis cells. The anode stack inlet and the cathode stack inlet of a certain stack can be jointly connected to the header. That is, a respective header outlet assigned to the respective stack can be connected to both the anode stack inlet and the cathode stack inlet of this stack. To this end, the single feed does not only fan out to the individual stacks by means of the header, but further to the anode stack inlet and the cathode stack inlet. In case a stack has more than one stack inlet it is preferred that the respective control valve is arranged upstream of where a common flow assigned to this stack is divided into respective flows for the stack inlets.

[0014] In a second embodiment there are two pump units. In that case it is preferred that each of the stacks has a respective anode stack inlet and a respective cathode stack inlet. A pump unit outlet of a first of the pump units is connected to all anode stack inlets via a first header and a pump unit outlet of a second of the pump units is connected to all cathode stack inlets via a second header. This does not mean that the pump units have to be connected directly to the stack inlets. In particular, a respective means for returning excess flow to the separators to balance the feed medium flow can be arranged in between the pump unit and the respective stack inlets. The first header is provided for separating a flow of the medium provided by the first pump unit into a respective flow for each of the anode stack inlets. The second header is provided for separating a flow of the medium provided by the second pump unit into a respective flow for each of the cathode stack inlets. That is, by means of the first header a flow of the medium is distributed to the anode stack inlets and by means of the second header a flow of the medium is distributed to the cathode stack inlets. In this instance, and in particular for alkaline systems, a portion of the feed flows can be mixed in the separators to ensure a balance of electrolyte concentration is maintained. This embodiment can also be referred to as a separate feed because the medium is fed separately to the anode stack inlets and to the cathode stack inlets. In line with this, the anode separator is connected to an inlet of the first pump unit, but not to the second pump unit and the cathode separator is connected to an inlet of the second pump unit, but not to the first pump unit. That is, the medium can be circulated separately in an anode circulation and a cathode circulation.

[0015] In any case there is at least one control valve per stack. Thereby, it is possible to individually control the flow of the medium into the stacks. This allows multiple stacks to be used with a single anode separator and a single cathode separator. With the electrolysis arrangement a high degree of pressure control is possible. This is advantageous because it is desired to operate the electrolysis cells at precisely controlled pressures. The membrane of the electrolysis cells is preferably largely impermeable to the medium. However, a larger pressure difference between the anode space and the cathode space can drive greater amounts of the medium through the membrane. If too much of the medium is driven through the membrane, a hydrostatic imbalance between the anode separator and the cathode separator can be the result. In order to avoid this, it is desired to control the pressure difference between the anode space and the cathode space. In particular, it is preferred that for each of the stacks a respective pressure difference between the anode space and the cathode space is smaller than 0.05 bar, in particular smaller than 0.02 bar.

[0016] In order to achieve such a precise pressure control, the electrolysis arrangement comprises a respective control valve for each of the stacks. The control valve is arranged between the header and the stack inlet of the respective stack. In the first embodiment with only one pump unit and only one header the control valve is arranged between the stack inlet and the one header. Also in case each of the stacks has more than one stack inlet, it is sufficient that only one control valve is provided for each of the stacks. This is the case for a common medium feed to each stack, which is then split downstream of the control valve to the anode inlet and cathode inlet. In that case it is preferred that the respective control valve is arranged between the header and a point where a flow from the header is divided into separate flows for the individual stack inlets. In the second embodiment with two pump units and two headers the control valves are arranged between the respective stack inlet and the header to which this stack inlet is connected. It is preferred that for each stack a respective first control valve is provided between the first header and the anode stack inlet and a respective second control valve is provided between the second header and the cathode stack inlet.

[0017] It is preferred that the pump units provide a pressure that is at least 1 bar higher than the desired pressure at the stack inlets. The control valves can be used to reduce the pressure.

[0018] According to a preferred embodiment the electrolysis arrangement is configured such that for all of the stacks a respective pressure drop from a first point between the header and the respective control valve to a second point within the anode separator downstream of the respective anode separator inlet has the same value within a tolerance of 0.3 bar, more preferably within 0.1 bar

and/or

such that for all of the stacks a respective pressure drop from a third point between the header and the respective control valve to a fourth point within the cathode separator downstream of the respective cathode separator inlet has the same value within a tolerance of 0.3 bar, more preferably within 0.1 bar. The "and" case is preferred.

[0019] This embodiment is directed to the pressure drop across the stack with respect to the anodes and/or to the pressure drop across the stack with respect to the cathodes. This means that a comparison among the pressure drops with respect to the anodes is performed and/or that a comparison among the pressure drops with respect to the anodes is performed.

[0020] With respect to the anodes, the pressure drop is defined between a first point and a second point. For each of the stacks a respective first point and a respective second point are defined. The second point can be the same for all stacks. For each of the stacks the pressure at the respective first point is compared with the pressure at the respective second point. Thereby, for each of the stacks a respective pressure difference is obtained. The pressure differences of the stacks are, within a tolerance of 0.3 bar, the same for all stacks. That is, the obtained pressure difference for a certain stack differs by not more than 0.3 bar from the respective pressure difference obtained for any of the other stacks. Thereby, only the pressure drop with respect to the anodes are taken into account. The first point is located between the header and the control valve. In case there are multiple headers and separate anode and cathode stack inlets this refers to the header that is connected to the anode stack inlet and to the control valve upstream of the anode stack inlet. In the above described second embodiment this would be the first header. The second point is located within the anode separator downstream of the respective anode separator inlet. That means that a pressure drop caused by the anode separator inlet is taken into account in the described pressure drop the present embodiment is directed to.

[0021] An analogous description applies to the pressure drop with respect to the cathodes. With respect to the cathodes, the pressure drop is defined between a third point and a fourth point. For each of the stacks a respective third point is defined, whereas the fourth point is the same for all stacks. For each of the stacks a respective third point and a respective fourth point are defined. The fourth point can be the same for all stacks. For each of the stacks the pressure at the respective third point is compared with the pressure at the respective fourth point. The comparison of the obtained pressure differences is analogous to what has been described with respect to the anodes.

[0022] According to a further preferred embodiment of the electrolysis arrangement the stacks each have a maximum rated DC power consumption in the range of 1 to 20 MW, in particular in the range of 3 to 10 MW.

[0023] The described electrolysis arrangement is preferably used for industrial scale electrolysis. In particular, this is to be understood in contrast to experimental setups on a laboratory scale. In the present embodiment the industrial scale is quantified in terms of the maximum rated DC power consumption of the stacks. The maximum rated DC power consumption is what is commonly used to describe the electrolysis stacks. For example, a "5 MW stack" has a maximum rated DC power consumption of 5 MW.

[0024] The total maximum rated DC power consumption of the electrolysis arrangement is the sum of the respective maximum rated DC power consumptions of the stacks. The total maximum rated DC power consumption of the electrolysis arrangement is preferably in the range of 10 to 80 MW. In particular with such a total maximum rated DC power consumption it would be inefficient to have a respective anode separator and a respective cathode separator for each of the stacks, as is the case in the prior art.

[0025] According to a further preferred embodiment of the electrolysis arrangement the at least one pump unit comprises a centrifugal pump configured to provide an adjustable flow of the medium.

[0026] Centrifugal pumps are particularly suitable for industrial scale electrolysis. To this end, the present embodiment points out that the described electrolysis arrangement is directed to industrial scale electrolysis, and not to laboratory scale electrolysis. In case there are multiple pump units, it is preferred that all pump units comprise a respective centrifugal pump configured to provide a respective adjustable flow of the medium. In case a pump unit comprises more than one pump, it is preferred that all these pumps are the pumps are centrifugal pumps. In particular, it is preferred that all pumps of the electrolysis arrangement are centrifugal pumps.

[0027] Alternatively, one or more of the pumps can be a mechanical gear pump could be used.

[0028] According to a further preferred embodiment of the electrolysis arrangement a cooler and/or a filter are arranged between the at least one pump unit and the respective header. The "and" case is preferred.

[0029] In the present embodiment not only the anode separator, the cathode separator and the at least one pump unit can be shared by the multiple stacks, but also the cooler and/or the filter. This further simplifies the electrolysis arrangement and reduces costs.

[0030] In case there are multiple pump units, it is preferred that for each of the pump units a respective cooler and/or a respective filter are arranged between the pump unit and the respective header.

[0031] According to a further preferred embodiment of the electrolysis arrangement the electrolysis cells are configured as PEM electrolysis cells, anion exchange membrane electrolysis cells or alkaline electrolysis cells.

[0032] It was found that in particular using these electrolysis cells the described advantages can be obtained. PEM electrolysis cells are particularly preferred. In this case as well as potentially in the case of anion exchange membrane electrolysis cells the medium is water, in particular de-ionised water. In case of alkaline electrolysis cells and possibly anion exchange membrane electrolysis cells the medium is an aqueous solution of potassium hydroxide (KOH).

[0033] According to a further preferred embodiment of the electrolysis arrangement each of the anode separator inlets is configured as a nozzle and/or wherein each of the cathode separator inlets is configured as a nozzle. The "and" case is preferred.

[0034] The anode separator inlets are arranged between the first points and the second point(s). That is, the anode separator inlets configured as a nozzle contribute to the pressure drops across the stack as defined between the first points and the second point(s). This pressure drop can be adjusted, in particular, by adjusting the nozzles. This can mean that an adjustable nozzle is used and/or that the nozzle design is adjusted. That is, the nozzle design can be used to achieve pressure drops within the above described tolerance. Preferably, the dominant pressure drop is delivered by the control valve and the nozzle.

[0035] According to a further preferred embodiment of the electrolysis arrangement for the stacks a respective pipe length between the anode outlets and the anode separator inlets differ by less than 50 %, preferably by less than 30 % and more preferably by less than 10 %, and/or for the stacks a respective pipe length between the cathode outlets and the cathode separator inlets differ by less than 50 %, preferably by less than 30 % and more preferably by less than 10 %. The "and" case is preferred.

[0036] The pipe length between an anode outlet and an anode separator inlet is the distance between the anode outlet and the anode separator inlet measured along a pipe that connects the anode outlet and the anode separator inlet. An analogous description applies with respect to the cathodes. The more uniform the pipe lengths downstream of the stacks are, the easier can the same pressure be obtained at all stack inlets. This is due to the fact that the pressure at the stack inlets is, in particular, influenced by the backpressure caused downstream of the stacks.

[0037] According to a further preferred embodiment of the electrolysis arrangement the anode separator is arranged horizontally and/or the cathode separator is arranged horizontally. The "and" case is preferred.

[0038] It was found that with horizontal separators it is easier to achieve uniform pipe lengths from the different stacks to the separator. Further, the formation of foam and entrained bubbles is less likely with horizontal separators, since the design more readily accommodates quiescent zones and discourages a natural circulation of bubbles. Horizontal separators are particularly preferred in case the electrolysis cells are alkaline electrolysis cells.

[0039] According to a further preferred embodiment the electrolysis arrangement further comprises a bypass from a point between the at least one pump unit and the respective header to the anode separator and/or to the cathode separator. The "and" case is preferred.

[0040] In case there is only one pump unit, the bypass preferably extends from a point between the pump unit and the header and, via a first outlet branch, to the anode separator and, via a second outlet branch, to the cathode separator. In case there are multiple pump units, the bypass preferably has a respective inlet branch for each of the pump units, wherein each of the inlet branches begins between the pump unit and the respective header. Also in this case the bypass preferably terminates at the anode separator via a first outlet branch and at the cathode separator via a second outlet branch.

[0041] Via the bypass the medium can flow from the pump unit outlet to the pump unit inlet without passing the stacks. Thereby, the pump unit(s) can generate a flow that is higher than required. Preferably, the bypass comprises a bypass valve. By means of the bypass valve the flow through the bypass and, in consequence, through the stacks can be adjusted particularly quickly, in particular compared to adjusting the rotation speed of one or more pumps of the pump unit. Hence, in the present embodiment the flow control is particularly fast.

[0042] The anode separator and the cathode separator are preferably connected to each other only via the separator outlets, the separator inlets and/or via the bypass. The bypass can be used to balance the medium level in the anode separator and the cathode separator.

[0043] As a further aspect of the invention a method for performing an electrolysis of a medium in order to obtain an anode product and a cathode product using an electrolysis arrangement as described is presented. The method comprises driving the medium by means of the at least one pump unit and applying a voltage to the electrolysis cells, wherein the speed of at least one pump of the at least one pump unit and the settings of the control valves are controlled.

[0044] The advantages and features of the electrolysis arrangement are transferrable to the method, and vice versa. The electrolysis arrangement is preferably configured to be used according to the method. The voltage is applied such that the anode product and the cathode product are obtained from the medium by electrolysis.

[0045] According to a preferred embodiment of the method the at least one pump unit and/or the control valves are controlled such that the at least one pump unit provides the medium with a pressure that is at least 0.4 bar higher than the pressure at each of the stack inlets. The "and" case is preferred.

[0046] Providing the medium at a pressure higher than required was found to be advantageous in order to compensate for a pressure drop caused by the control valves.

[0047] According to further a preferred embodiment of the method the at least one pump unit is controlled based on a total flow demand.

[0048] The load of the at least one pump unit is preferably not controlled based on an amount of the anode product or of the cathode product that are supposed to be produced. In particular, in the case of hydrogen production the load of the at least one pump unit is preferably not controlled based on an amount of hydrogen that is supposed to be produced. Instead, the load of the at least one pump unit is controlled based on the total flow demand. The total flow demand is the sum of the respective flow demands of the stacks and, optionally, of a bypass flow. The flow demand of a stack can be determined based on an inherent age of the stack, a power factor of the stack and/or a harmonic distortion limit of the stack. The inherent age of a stack is a measure that can be seen, for example in the case of hydrogen production, from the power demand for a given amount of hydrogen that is supposed to be obtained. In determining the total flow demand it is preferably taken into account which of the stacks are in operation.

[0049] According to further a preferred embodiment of the method the control valves are controlled based on

- an amount of the anode product that is supposed to be obtained and/or an amount of the cathode product that is supposed to be obtained,
- a maximum difference of the temperature of the medium at the anode outlet and the cathode outlet of the respective stack,

- a maximum temperature of the medium at the anode outlet of the respective stack and/or a maximum temperature of the medium at the cathode outlet of the respective stack,
- a predetermined minimum flow through the respective stack,
- a predetermined maximum flow through the respective stack, and/or
- a pressure differential between different stack inlets of the same stack.

[0050] Preferably, the control valves are controlled based on at least three of these eight parameters. More preferably, all parameters are used.

[0051] The amount of the anode product that is supposed to be obtained and the amount of the cathode product that is supposed to be obtained describe a production request that may be issued by a control system. The difference of the temperature of the medium at the anode outlet and the cathode outlet is preferably in the range of 10 and 15 °C. The maximum temperature of the medium at the anode outlet can also be considered the maximum outlet temperature of the stack. This parameter is an operating constraint. Providing a predetermined minimum flow can ensure efficient stack operation for a given production rate. A predetermined maximum flow can be provided to ensure that the stacks are not damaged.

[0052] According to further a preferred embodiment of the method a pressure of the medium at the stack inlets is within the range of 5 to 50 bar.

[0053] The electrolysis is preferably a high pressure electrolysis. In the present embodiment this is quantified in terms of the pressure at the stack inlets.

[0054] In the following the invention will be described with respect to the figures. The figures show preferred embodiments, to which the invention is not limited. The figures and the dimensions shown therein are only schematic. The figures show:

Fig. 1: a first embodiment of an electrolysis arrangement according to the invention, and

Fig. 2: a second embodiment of an electrolysis arrangement according to the invention.

[0055] Fig. 1 shows an electrolysis arrangement 1 that comprises multiple stacks 3 of electrolysis cells. The electrolysis cells may be configured as PEM electrolysis cells, anion exchange membrane electrolysis cells or alkaline electrolysis cells. The stacks 3 each have a maximum rated DC power consumption in the range of 1 to 20 MW. Also, the electrolysis arrangement 1 comprises a pump unit 2 for driving a medium. In the present embodiment there is only one pump unit 2. Hence, the present embodiment can be referred to as a single feed. In the embodiment of Fig. 1, the pump unit 2 comprises a single pump only.

[0056] The pump unit 2 comprises a centrifugal pump configured to provide an adjustable flow of the medium. Each stack 3 comprises two stack inlets 4a,4b that are connected to the pump unit 2 via a header 5 for separating a flow of the medium provided by the pump unit 2 into a respective flow for each of the stacks 3. Between the pump unit 2 and the header 5 a cooler 21 and a filter 22 are arranged. Further, each stack 3 comprises a respective anode outlet 6 and a respective cathode outlet 7. The stacks 3 are configured to obtain by electrolysis of the medium introduced into the respective stack inlets 4a,4b an anode product provided together with the medium at the respective anode outlet 6 and a cathode product provided together with the medium at the respective cathode outlet 7.

[0057] Further, the electrolysis arrangement 1 comprises a respective control valve 8 for each of the stacks 3 arranged between the header 5 and the respective stack inlets 4a,4b, wherein the control valves 8 are configured to individually control a flow of the medium into the respective stack 3. This does not necessarily mean that the flow into the anode stack inlet 4a can be controlled independently of the flow into the cathode stack inlet 4b. In the embodiment according to Fig. 1 this is not possible because the flow assigned to a certain stack 3 is divided into separate flows for the anode stack inlet 4a and the cathode stack inlet 4b downstream of the control valve 8. Nevertheless, the flow into the stack inlets 4a,4b of one stack 3 can be controlled independently of the flow into the stack inlets 4a,4b of the other stacks 3.

[0058] The electrolysis arrangement 1 further comprises an anode separator 9 having an anode separator medium outlet 12 that is connected to the pump unit 2. Each of the anode outlets 6 of the stacks 3 is connected to a respective anode separator inlet 10 of the anode separator 9. The anode separator 9 is configured to separate the anode product from the medium introduced into the anode separator inlets 10 such that the anode product is provided at an anode separator product outlet 11 and the medium is provided at the anode separator medium outlet 12. The pressure of the anode separator 9 is controlled by a control valve 25. The electrolysis arrangement 1 further comprises a cathode separator 13 having a cathode separator medium outlet 16 that is connected to the pump unit 2. Each of the cathode outlets 7 of the stacks 3 is connected to a respective cathode separator inlet 14 of the cathode separator 13. The cathode separator 13 is configured to separate the cathode product from the medium introduced into the cathode separator inlets 14 such that the cathode product is provided at a cathode separator product outlet 15 and the medium is provided at the cathode separator medium outlet 16. The pressure of the cathode separator 13 is controlled by a control valve 26. The operation of the control valves 25 and 26 are such that the pressure difference is minimized between the two separators 9,13.

[0059] The anode separator 9 and the cathode separator 13 are arranged horizontally. In particular thereby it is possible that a respective pipe length between the anode outlets 6 and the anode separator inlets 10 for the stacks 3 differ by less than 50 % and that a respective pipe length between the cathode outlets 7 and the cathode separator inlets 14 for the stacks 3 differ by less than 50 %. Each of the anode separator inlets 10 is configured as a nozzle and each of the cathode separator inlets 14 is configured as a nozzle.

[0060] The electrolysis arrangement 1 is configured such that for all of the stacks 3 a respective pressure drop from a first point 17 between the header 5 and the respective control valve 8 to a second point 18 within the anode separator 9 downstream of the respective anode separator inlet 10 has the same value within a tolerance of 0.3 bar and such that for all of the stacks 3 a respective pressure drop from a third point 19 between the header 5 and the respective control valve 8 to a fourth point 20 within the cathode separator 13 downstream of the respective cathode separator inlet 14 has the same value within a tolerance of 0.3 bar. In the present embodiment the first point 17 and the third point 19 are the same.

[0061] The electrolysis arrangement 1 further comprises a bypass 23 from a point between the pump unit 2 and the header 5 to the anode separator 9 and to the cathode separator 13.

[0062] Fig. 2 shows a further embodiment of an electrolysis arrangement 1. In contrast to the embodiment of Fig. 1, there are two pump units 2. Hence, the embodiment of Fig. 2 can be referred to as a separate feed. In the following, merely the differences to the embodiment of Fig. 1 are described. In the embodiment of Fig. 2, each of the pump units 2 have a single pump.

[0063] The pump units 2 each comprise a respective centrifugal pump configured to provide a respective adjustable flow of the medium. Each stack 3 comprises two stack inlets 4a,4b. A respective anode stack inlet 4a is connected to one of the pump units 2 via a header 5, while a respective cathode stack inlet 4b is connected to the other pump unit 2 via a further header 5. Between each of the pump units 2 and the respective header 5 a respective cooler 21 and respective filter 22 are arranged. The electrolysis arrangement 1 comprises two respective control valves 8 for each of the stacks 3. For each stack 3, one control valve 8 is arranged between the anode stack inlet 4a and the header 5 connected thereto and one control valve 8 is arranged between the cathode stack inlet 4b and the header 5 connected thereto. The control valves 8 are configured to individually control a flow of the medium into the respective stack inlets 4a,4b. In this embodiment this means that the flow into the anode stack inlet 4a can be controlled independently of the flow into the cathode stack inlet 4b as well as that the flows into the stack inlets 4a,4b of one stack 3 can be controlled independently of the flows into the stack inlets 4a,4b of the other stacks 3. In addition, the need to minimize the pressure difference between the inlet 4a and 4b may require a minor additional flow control on one of the two streams downstream of one of the two valve 8.

[0064] The electrolysis arrangement 1 further comprises an anode separator 9 having an anode separator medium outlet 12 that is connected to each of the pump units 2. Also, the electrolysis arrangement 1 comprises a cathode separator 13 having a cathode separator medium outlet 16 that is connected to each of the pump units 2.

[0065] The electrolysis arrangement 1 is configured such that for all of the stacks 3 a respective pressure drop from a first point 17 between the header 5 and the respective control valve 8 assigned to the anode stack inlet 4a to a second point 18 within the anode separator 9 downstream of the respective anode separator inlet 10 has the same value within a tolerance of 0.3 bar and such that for all of the stacks 3 a respective pressure drop from a third point 19 between the header 5 and the respective control valve 8 assigned to the cathode stack inlet 4b to a fourth point 20 within the cathode separator 13 downstream of the respective cathode separator inlet 14 has the same value within a tolerance of 0.3 bar. In contrast to the embodiment of Fig. 1, in the present embodiment the first points 17 and the third points 19 are not the same.

[0066] The invention can be summarized as follows: An electrolysis arrangement 1 is provided that comprises:

- a pump unit 2,
- multiple stacks 3,
- a respective control valve 8 for each of the stacks 3,
- an anode separator 9, and
- a cathode separator 13.

[0067] Due to the control valves 8 assigned to each of the stacks 3 an independent flow control can be achieved for the stacks 3. This allows safe and reliable operation of the electrolysis arrangement 1 although multiple stacks 3 are connected to the same anode separator 9 and to the same cathode separator 13.

List of reference numerals

[0068]

1	Electrolysis arrangement
2	pump unit
3	stack
4a	anode stack inlet
4b	cathode stack inlet
5	header
6	anode outlet
7	cathode outlet
8	control valve
9	anode separator
10	anode separator inlet
11	anode separator product outlet
12	anode separator medium outlet
13	cathode separator
14	cathode separator inlet
15	cathode separator product outlet
16	cathode separator medium outlet

17 first point
18 second point
19 third point
20 fourth point
21 cooler
22 filter
23 bypass
24 bypass valve
25 control valve
26 control valve

Claims

1. Electrolysis arrangement (1) comprising:

- at least one pump unit (2) for driving a medium,
- multiple stacks (3) of electrolysis cells, wherein each stack (3) comprises a stack inlet (4a,4b) that is connected to one of the pump units (2) via a header (5) for separating a flow of the medium provided by the respective pump unit (2) into a respective flow for each of the stacks (3), and wherein each stack (3) comprises a respective anode outlet (6) and a respective cathode outlet (7), wherein the stacks (3) are configured to obtain by electrolysis of the medium introduced into the respective stack inlet (4a,4b) an anode product provided together with the medium at the respective anode outlet (6) and a cathode product provided together with the medium at the respective cathode outlet (7),
- for each of the stacks (3) a respective control valve (8) arranged between the header (5) and the respective stack inlet (4a,4b), wherein the control valves (8) are configured to individually control a flow of the medium,
- an anode separator (9) having an anode separator medium outlet (12) that is connected to one of the pump units (2), wherein each of the anode outlets (6) of the stacks (3) is connected to a respective anode separator inlet (10) of the anode separator (9), and wherein the anode separator (9) is configured to separate the anode product from the medium introduced into the anode separator inlets (10) such that the anode product is provided at an anode separator product outlet (11) and the medium is provided at the anode separator medium outlet (12) and,
- a cathode separator (13) having a cathode separator medium outlet (16) that is connected to one of the pump units (2), wherein each of the cathode outlets (7) of the stacks (3) is connected to a respective cathode separator inlet (14) of the cathode separator (13), and wherein the cathode separator (13) is configured to separate the cathode product from the medium introduced into the cathode separator inlets (14) such that the cathode product is provided at a cathode separator product outlet (15) and the medium is provided at the cathode separator medium outlet (16).

2. Electrolysis arrangement (1) according to claim 1, configured such that for all of the stacks (3) a respective pressure drop from a first point (17) between the header (5) and the respective control valve (8) to a second point (18) within the anode separator (9) downstream of the respective anode separator inlet (10) has the same value within a tolerance of 0.3 bar and/or
such that for all of the stacks (3) a respective pressure drop from a third point (19) between the header (5) and the respective control valve (8) to a fourth point (20) within the cathode separator (13) downstream of the respective cathode separator inlet (14) has the same value within a tolerance of 0.3 bar.

3. Electrolysis arrangement (1) according to any of the preceding claims, wherein the stacks (3) each have a maximum rated DC power consumption in the range of 1 to 20 MW.

4. Electrolysis arrangement (1) according to any of the preceding claims, wherein the at least one pump unit (2) comprises a centrifugal pump configured to provide an adjustable flow of the medium.

5. Electrolysis arrangement (1) according to any of the preceding claims, wherein a cooler (21) and/or a filter (22) are arranged between the at least one pump unit (2) and the respective header (5).

6. Electrolysis arrangement (1) according to any of the preceding claims, wherein the electrolysis cells are configured as PEM electrolysis cells, anion exchange membrane electrolysis cells or alkaline electrolysis cells.

7. Electrolysis arrangement (1) according to any of the preceding claims, wherein each of the anode separator inlets (10) is configured as a nozzle and/or wherein each of the cathode separator inlets (14) is configured as a nozzle.

8. Electrolysis arrangement (1) according to any of the preceding claims, wherein for the stacks (3) a respective pipe length between the anode outlets (6) and the anode separator inlets (10) differ by less than 50 % and/or wherein for the stacks (3) a respective pipe length between the cathode outlets (7) and the cathode separator inlets (14) differ by less than 50 %.

9. Electrolysis arrangement (1) according to any of the preceding claims, wherein the anode separator (9) is arranged horizontally and/or the cathode separator (13) is arranged horizontally.

10. Electrolysis arrangement (1) according to any of the preceding claims, further comprising a bypass (23) from a point between the at least one pump unit (2) and the respective header (5) to the anode separator (9) and/or to the cathode separator (13).

11. Method for performing an electrolysis of a medium in order to obtain an anode product and a cathode product using an electrolysis arrangement (1) according to any of the preceding claims, the method comprising driving the medium by means of the at least one pump unit (2) and applying a voltage to the electrolysis cells, wherein the speed of at least one pump of the at least one pump unit (2) and the settings of the control valves (8) are controlled.

12. Method according to claim 11, wherein the at least one pump unit (2) and/or the control valves (8) are controlled such that the at least one pump unit (2) provides the medium with a pressure that is at least 0.4 bar higher than the pressure at each of the stack inlets (4a,4b).

13. Method according to claim 11 or 12, wherein the at least one pump unit (2) is controlled based on a total flow demand.

14. Method according to any one of the claims 11 to 13, wherein the control valves (8) are controlled based on

- an amount of the anode product that is supposed to be obtained and/or an amount of the cathode product that is supposed to be obtained,
- a maximum difference of the temperature of the medium at the anode outlet (6) and the cathode outlet (7) of the respective stack (3),
- a maximum temperature of the medium at the anode outlet (6) of the respective stack (3) and/or a maximum temperature of the medium at the cathode outlet (7) of the respective stack (3),
- a predetermined minimum flow through the respective stack (3),
- a predetermined maximum flow through the respective stack (3), and/or
- a pressure differential between different stack inlets (4a,4b) of the same stack (3).

15. Method according to any one of the claims 11 to 14, wherein a pressure of the medium at the stack inlets (4a,4b) is within the range of 5 to 50 bar.

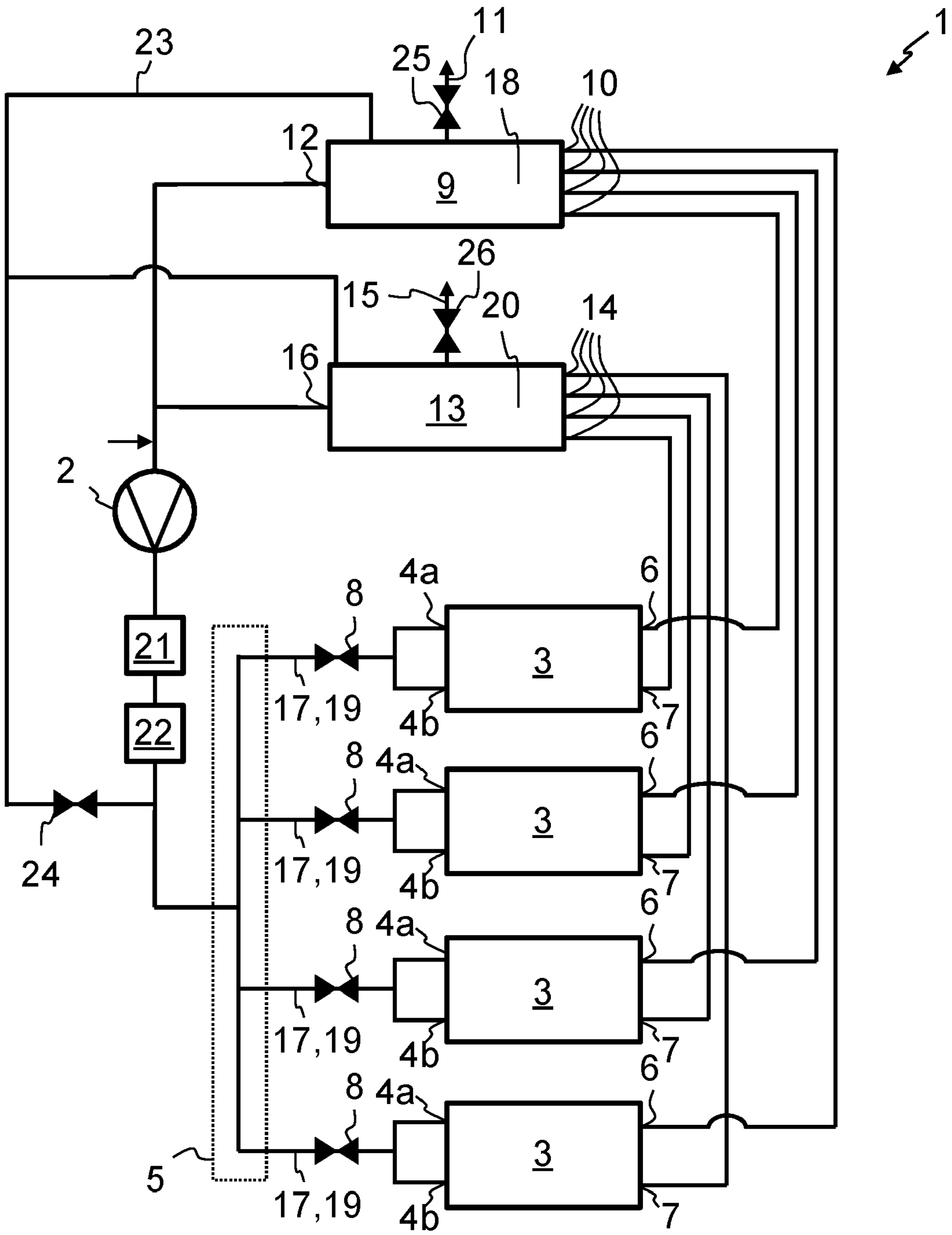

Fig. 1

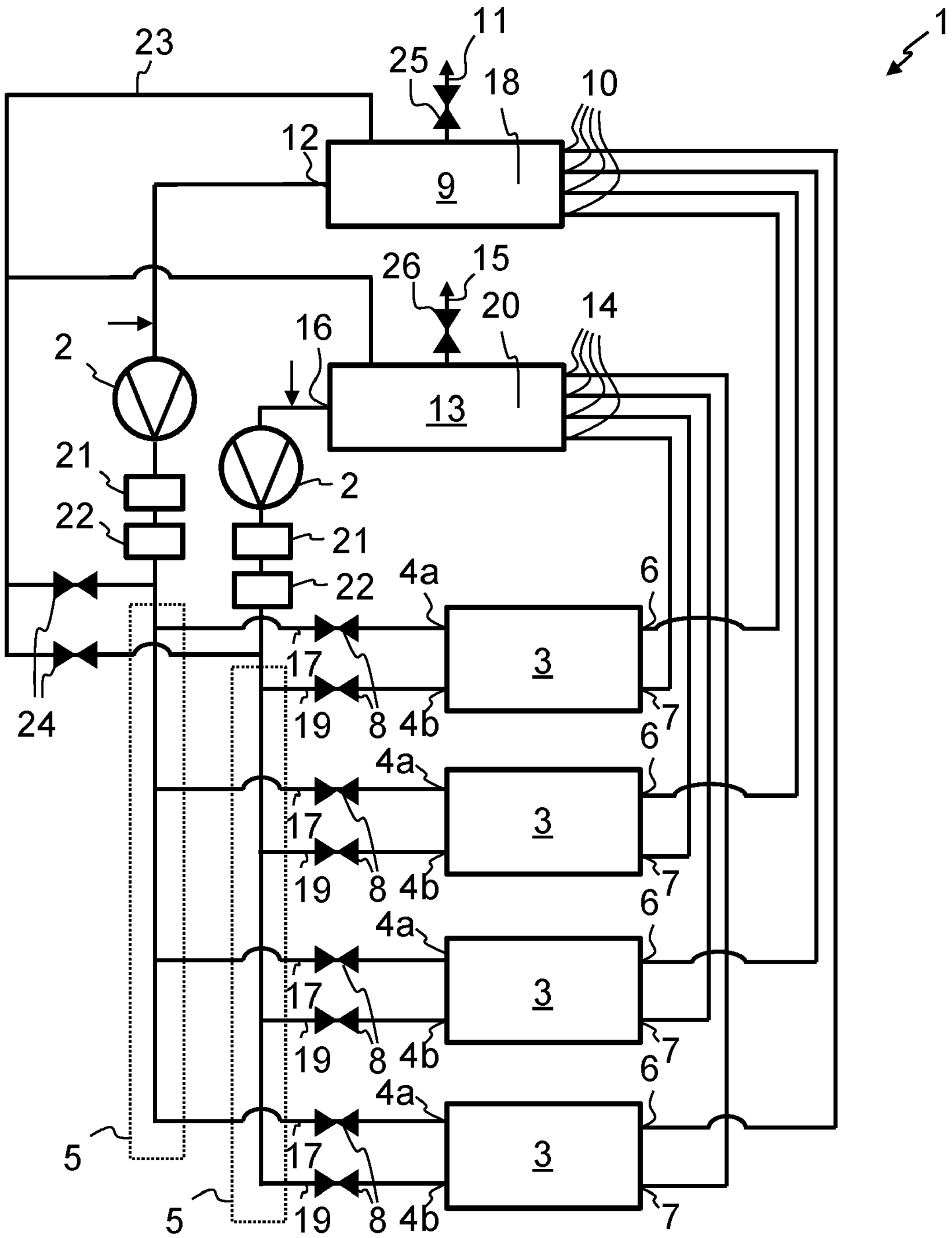
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Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 20 20 7789

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2005/121315 A1 (BALTRUCKI JUSTIN D [US] ET AL) 9 June 2005 (2005-06-09) * paragraph [0030] - paragraph [0037]; figures 2-4 * * paragraphs [0006], [0007] * -----	1-15	INV. C25B1/04 C25B9/70 C25B15/023 C25B15/08
			TECHNICAL FIELDS SEARCHED (IPC)
			C25B

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	17 April 2021	Desbois, Valérie

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17-04-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005121315 A1	09-06-2005	CA 2548767 A1	23-06-2005
		EP 1719197 A2	08-11-2006
		US 2005121315 A1	09-06-2005
		US 2010108535 A1	06-05-2010
		WO 2005057686 A2	23-06-2005

EPO FORM P0459

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