

(19)



(11)

EP 4 582 590 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

09.07.2025 Bulletin 2025/28

(51) International Patent Classification (IPC):

C25B 1/04 (2021.01) **C25B 15/08** (2006.01)

(21) Application number: **24150671.6**

(52) Cooperative Patent Classification (CPC):

C25B 1/04; C25B 15/08; C25B 15/083;
C25B 15/085; C25B 15/087

(22) Date of filing: **08.01.2024**

(84) Designated Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR

Designated Extension States:

BA

Designated Validation States:

KH MA MD TN

(72) Inventors:

- **Choudar, Yann**
60388 Frankfurt (DE)
- **Nesselberger, Markus**
60439 Frankfurt (DE)
- **Tadiello, Jean-Philippe**
60439 Frankfurt (DE)

(71) Applicant: **L'AIR LIQUIDE, SOCIETE ANONYME**
POUR L'ETUDE ET
L'EXPLOITATION DES PROCEDES GEORGES
CLAUDE
75007 Paris (FR)

(74) Representative: **Air Liquide**

L'Air Liquide S.A.
Direction de la Propriété Intellectuelle
75, Quai d'Orsay
75321 Paris Cedex 07 (FR)

(54) **ELECTROLYSIS WITH DOWNSTREAM STRATIFYING PIPE**

(57) Arrangement (1) for electrolysis comprising:

- an electrolysis stack (2) having an anode side (4) and a cathode side (3),
- a first separator (6.1) for separating a first gas flow (8.1) and a first liquid electrolyte flow (9.1),
- a first pipe (5.1), which is oriented along a first horizontal axis (12.1), and which has a first pipe end opening (10.1) and a second pipe end opening (11.1),

wherein the first pipe end opening (10.1) of the first pipe (5.1) is fluidly connected to the electrolysis stack (2), wherein the second pipe end opening (11.1) of the first pipe (5.1) is fluidly connected to an inlet (13.1) of the first separator (6.1), and wherein a first ratio defined as a free flow area (A_{P1}) of the first pipe (5.1) divided by a free flow area (A_{S1}) of the first separator (6.1) is in the range of 0.002 to 0.6.

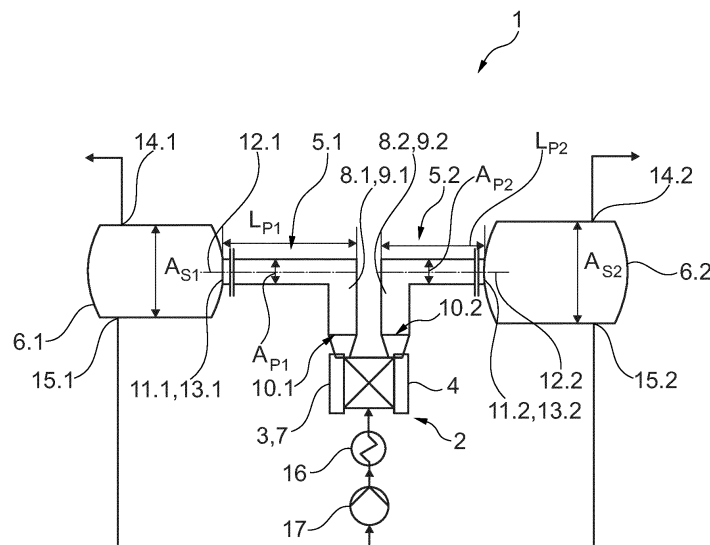


Fig. 1

Description

[0001] The present invention relates to an arrangement for electrolysis and a method to operate the arrangement.

[0002] As is known, an arrangement for electrolysis, e.g., alkaline water electrolysis, comprises an electrolyser with single or multiple electrolysis stacks and a gas-liquid separator. The electrolysis stack comprises pairs of electrodes operating in a liquid electrolyte solution. Those electrodes are allocated to a respective electrode side, the cathode side, and the anode side. The electrodes are structurally separated by a diaphragm. As a result, two product gases, e.g., oxygen and hydrogen, can be produced separately and discharged separately. The liquid electrolyte on the cathode side is called catholyte, the liquid electrolyte on the anode side is called anolyte. From the cathode side and from the anode side, a respective biphasic mixture of liquid electrolyte and product gas flows to the respective gas-liquid separator. It is known to recycle the respective electrolyte with a certain recycle rate and to mix them again with the electrolyte in the electrolyser.

[0003] Gas-liquid separators are known. Commonly, gas-liquid separators are designed as gravity separators operating according to the gravity effect, wherein the gravity separator is composed of a cylindrical vessel placed horizontally or vertically.

[0004] A limited efficiency of the gas-liquid separator and a high recycle rate can lead to product gas bubbles in the liquid electrolyte carry over to the liquid electrolyte in the electrolyser.

[0005] In detail, due to recycling, hydrogen bubbles in the catholyte can be carried over from the cathode side via the separator to the anode side of the electrolyser. Oxygen bubbles in the anolyte can be carried over from the anode side via the separator to the cathode side of the electrolyser. This crossover can lead to higher contamination of hydrogen with oxygen and/or higher contamination of oxygen with hydrogen. Increased contamination might generate an explosive mixture after reaching a lower explosive limit, or a higher explosive limit in the case of a Hydrogen atmosphere getting additional Oxygen.

[0006] An object of the present invention is to increase the separation efficiency of a liquid and a gas from a biphasic flow of an electrolysis stack and preventing explosive gas mixtures in an arrangement for electrolysis to increase safety.

[0007] These tasks are solved with an arrangement and a method according to the independent claims. Further advantageous embodiments are given in the dependent claims. The features shown in the claims and in the description can be combined with one another in any technologically meaningful way.

[0008] According to the present invention, an arrangement for electrolysis is presented, which comprises an electrolysis stack having an anode side and a cathode

side, a first separator for separating a first gas flow and a first liquid electrolyte flow, and a first pipe. The first pipe is oriented along a first horizontal axis, and the first pipe has a first pipe end opening and a second pipe end opening.

[0009] The first pipe end opening of the first pipe is fluidly connected to the electrolysis stack, wherein the second pipe end opening of the first pipe is fluidly connected to an inlet of the first separator. A first ratio defined as a free flow area of the first pipe divided by a free flow area of the first separator is in the range of 0.002 to 0.6.

[0010] The arrangement can be used for electrolysis of a medium. Preferably, the medium is liquid, in particular water. Therein, it is not necessary that the medium is pure water. In particular, the medium may contain dissolved salts such as KOH for alkaline electrolysis or electrolysis using anion exchange membrane cells. The electrolysis products are gaseous.

[0011] The arrangement comprises an electrolysis stack. Preferably, the arrangement comprises multiple electrolysis stacks. However, since it is sufficient to have a single electrolysis stack, this case will be focussed on below. The electrolysis stack comprises multiple electrolysis cells. Within the electrolysis stack the electrolysis of the medium can be performed using the electrolysis cells.

[0012] Preferably, the arrangement is used for electrolysis in cases with a designed capacity of at least 100 kW.

[0013] The first gas flow can comprise the electrolysis products from the electrolysis stack. A first biphasic flow is a mixture of the first gas flow and the first liquid electrolyte flow that emanates from the electrolysis stack. In the first biphasic flow, the first gas flow can be entrapped partially in the first liquid electrolyte flow. In particular, the first gas flow can be formed partially as small bubbles in the first liquid electrolyte flow. In particular, the electrolysis stack can be pressurized. The first gas flow can then be formed as even smaller bubbles in the first liquid electrolyte flow.

[0014] The first pipe is configured to obtain a stratified flow regime of the first biphasic flow of the first liquid electrolyte flow and the first gas flow. In a stratified flow regime, a clear spatial difference between the first liquid electrolyte flow and the first gas flow can appear. The first gas flow can ascend to the top and the first liquid electrolyte flow can descend to the bottom of the first pipe due to their densities. The first gas flow and the first liquid electrolyte flow can be separated by an undisturbed flat interface.

[0015] Preferably, the first pipe is hollow. In particular, no barriers or obstructions for the first gas flow and for the first liquid electrolyte flow are arranged in the first pipe.

[0016] The first pipe end opening of the first pipe is fluidly connected to the electrolysis stack, wherein the second pipe end opening of the first pipe is fluidly connected to the inlet of the first separator.

[0017] In particular, the fact that the first pipe end opening of the first pipe is fluidly connected to the electrolysis stack can mean that there are further pipes and/or supply lines between the first pipe end opening of the first

pipe and the electrolysis stack. The fact that the second pipe end opening of the first pipe is fluidly connected to the inlet of the first separator can mean that there are further pipes and/or supply lines between the second pipe end opening of the first pipe and the electrolysis stack. Preferably, a flow is able to flow from the electrolysis stack to the first pipe end opening of the first pipe and from the second pipe end opening of the first pipe to the first separator.

[0018] In particular, the first pipe can be considered a connecting piece for the first gas flow and the first liquid electrolyte flow between the electrolysis stack and the first separator.

[0019] The first separator is configured to separate a liquid phase and a gaseous phase of an incoming flow from each other. In particular, the first separator is configured to separate the first liquid electrolyte flow and the first gas flow.

[0020] Preferably, the first separator is a gravity separator. Two components with different densities, are separated according to their densities. Components with lighter densities with respect to the heavier densities ascend, so that a vertical separation is accomplished. The first separator can be composed of a cylindrical vessel placed horizontally or vertically. It is particularly preferred that the first separator is a horizontally placed cylindrical vessel. The first separator can comprise a first end and an opposite second end.

[0021] The first gas flow and the first liquid electrolyte flow can be injected into the first separator via the inlet of the first separator. In particular, the inlet of the first separator is arranged at the first end of the first separator. Preferably, the inlet of the first separator is just as large as the second pipe end opening of the first pipe. The advantage of this is that turbulences are reduced and thus an unwanted mixture of first gas flow and first liquid electrolyte flow is avoided.

[0022] The first ratio defined as a free flow area of the first pipe divided by a free flow area of the first separator is in the range of 0.002 to 0.6. Preferably, the first ratio defined as a free flow area of the first pipe divided by a free flow area of the first separator is in the range of 0.0025 to 0.5625. Expressed in reformulated form, the first ratio defined as the square root of a free flow area of the first pipe divided by the square root of a free flow area of the first separator is in the range of 0.05 to 0.75.

[0023] Preferably, a cross-sectional area of the first pipe denotes the free flow area of the first pipe. It is particularly preferred that the free flow area of the first pipe and/or the cross-sectional area of the first pipe are constant over the pipe length of the first pipe. Preferably, a cross-sectional area of the first separator denotes the free flow area of the first separator. It is particularly preferred that the free flow area of the first separator and/or the cross-sectional area of the first separator are constant over the length of the first separator. The "and" cases are preferred.

[0024] Preferably, the cross-sectional area of the first

pipe is rectangular and/or the cross-sectional area of the first separator is rectangular. It is particularly preferred that the cross-sectional area of the first pipe is round and/or the cross-sectional area of the first separator is round. The "and" cases are preferred.

[0025] The advantage of the described configuration is that a flow regime of the biphasic mixture flow in the first pipe can be adjusted. A stratified flow regime can advantageously be reached. By reaching a stratified flow regime, a clear difference between the first gas flow and the first liquid electrolyte flow in the first pipe appears. In particular, reaching a stratified flow regime in the first pipe can mean that the first gas flow and the first liquid electrolyte flow in the first pipe are spatially separated due to their density. The first gas flow flows on top of the liquid electrolyte flow with a flat interface between the first gas flow and the second liquid electrolyte flow.

[0026] For this purpose, a flow velocity of the first gas flow and a flow velocity of the first liquid electrolyte flow in the first pipe can be reduced. Additionally, a turbulence of the first gas flow and a turbulence of the first liquid electrolyte flow in the first pipe can be reduced.

[0027] Advantage of the arrangement is that the separation efficiency of the first liquid electrolyte flow and the first gas flow can be increased and additionally, explosive gas mixtures in the arrangement are avoided. This is achieved in that the first liquid electrolyte flow and the first gas flow are not only separated from each other within the first separator, but partially already within the first pipe that leads to the first separator.

[0028] In a preferred embodiment of the arrangement, the first pipe has a length that is at least equal to the square root of the free flow area of the first pipe. Preferably, the first pipe has a length that is at least four times the square root of the free flow area of the first pipe divided by the square root of pi. In the case the first pipe has a circular cross-section, this means that the first pipe has a length that is at least twice the diameter of the first pipe.

[0029] Advantage of the embodiment is that that a stratified flow regime in the first pipe can be obtained particularly well. In particular, the stratified flow regime can be obtained at least towards the second pipe end opening of the first pipe.

[0030] In a further preferred embodiment of the arrangement, the first pipe is cylindrical, wherein the first pipe end opening is opposite to the second pipe end opening. It is preferred, but not necessary that the first pipe end opening of the first pipe and the second pipe end opening of the first pipe are the same size.

[0031] Advantage of the embodiment is that a stratified flow regime is achieved particularly well.

[0032] In a further preferred embodiment, the first pipe has an inner diameter, and the first separator has an inner diameter, and wherein a second ratio defined as the inner diameter of the first pipe divided by the inner diameter of the first separator is in the range of 0.05 to 0.75.

[0033] Preferably, the first separator is cylindrical.

[0034] Advantage of the embodiment is that the separation efficiency of first liquid electrolyte flow and the first gas flow can be increased and additionally, explosive gas mixtures in the arrangement are avoided.

[0035] In a further preferred embodiment of the arrangement based on the previous embodiment, the first pipe has a length that is at least equal to two times the inner diameter of the first pipe.

[0036] Advantage of the embodiment is that that a stratified flow regime in the first pipe can be obtained particularly well. In particular, the stratified flow regime can be obtained at least towards the second pipe end opening of the first pipe. Further advantage is that the length of the first separator can be particularly short.

[0037] In a further preferred embodiment of the arrangement, the first separator has a gas outlet, and the first separator has an electrolyte outlet. The gas outlet is arranged above the electrolyte outlet.

[0038] The first gas flow can be discharged from the first separator via the gas outlet. The first liquid electrolyte flow can be drained from the first separator via the electrolyte outlet. In particular, the first liquid flow has a higher density than the first gas flow. Following this condition, it is advantageous to arrange the gas outlet above the electrolyte outlet. Preferably, the gas outlet and the electrolyte outlet are vertically distanced from each other as far as possible. This could mean that the gas outlet is arranged at the top of the first separator and the electrolyte outlet is arranged at the bottom of the first separator.

[0039] Preferably, the gas outlet and the electrolyte outlet are arranged at the second end of the first separator.

[0040] Advantage of the embodiment is that the first gas flow and the first electrolyte flow can be separated particularly easily.

[0041] In an alternatively preferred embodiment of the arrangement, the first pipe is immediately connected to the inlet of the first separator.

[0042] Advantage of the embodiment is that an overall length of the first separator and the first pipe is particularly shortened.

[0043] In a further preferred embodiment of the arrangement, the arrangement further comprises a second separator for separating a second gas flow and a second liquid electrolyte flow, a second pipe, which is oriented along a second horizontal axis, and which has a first pipe end opening and a second pipe end opening, wherein the first pipe end opening of the second pipe is fluidly connected to the electrolysis stack, wherein the second pipe end opening of the second pipe is fluidly connected to an inlet of the second separator, and wherein a third ratio defined as a free flow area of the second pipe divided by a free flow area of the second separator is in the range of 0.002 to 0.6.

[0044] The second gas flow can comprise the electrolysis products from the electrolysis stack. A second biphasic flow is a mixture of the second gas flow and the second liquid electrolyte flow that emanates from the

electrolysis stack. In the second biphasic flow, the second gas flow can be entrapped partially in the second liquid electrolyte flow. In particular, the second gas flow can be formed partially as small bubbles in the second liquid electrolyte flow.

[0045] The second pipe is configured to obtain a stratified flow regime of the second biphasic flow of the second liquid electrolyte flow and the second gas flow. In a stratified flow regime, a spatial difference between the second liquid electrolyte flow and the second gas flow appears. The second gas flow ascends to the top and the second liquid electrolyte flow descends to the bottom of the second pipe due to their densities. The second gas flow and the second liquid electrolyte flow are separated by an undisturbed flat interface.

[0046] Preferably, the second pipe is hollow. It is particularly preferred that no barriers or obstructions for the second gas flow and for the second liquid electrolyte flow are arranged in the second pipe.

[0047] The first pipe end opening of the second pipe is fluidly connected to the electrolysis stack, wherein the second pipe end opening of the second pipe is fluidly connected to the inlet of the second separator.

[0048] In particular, the fact that the first pipe end opening of the second pipe is fluidly connected to the electrolysis stack can mean that there are further pipes and/or supply lines between the first pipe end opening of the second pipe and the electrolysis stack. The fact that the second pipe end opening of the second pipe is fluidly connected to the inlet of the second separator can mean that there are further pipes and/or supply lines between the second pipe end opening of the second pipe and the electrolysis stack. Preferably, a flow is able to flow from the electrolysis stack to the first pipe end opening of the second pipe and from the second pipe end opening of the second pipe to the second separator.

[0049] In particular, the second pipe can be considered a connecting piece for the second gas flow and the second liquid electrolyte flow between the electrolysis stack and the second separator.

[0050] The second separator is configured to separate the liquid phase and the gaseous phase of an incoming flow. In particular, the second separator is configured to separate the second liquid electrolyte flow and the second gas flow.

[0051] Preferably, the second separator is a gravity separator. The second separator can be composed of a cylindrical vessel placed horizontally or vertically. It is particularly preferred that the second separator is a horizontally placed cylindrical vessel. The second separator can comprise a first end and an opposite second end.

[0052] The second gas flow and the second liquid electrolyte flow are injected into the second separator via the inlet of the second separator. In particular, the inlet of the second separator is arranged at the first end of the second separator. Preferably, the inlet of the second separator is just as large as the second pipe end opening of the second pipe. The advantage of this is that turbu-

lences are reduced and thus an unwanted mixture of second gas flow and second liquid electrolyte flow is avoided.

[0053] A third ratio defined as a free flow area of the second pipe divided by a free flow area of the second separator is in the range of 0.002 to 0.6. Preferably, the third ratio defined as a free flow area of the second pipe divided by a free flow area of the second separator is in the range of 0.0025 to 0.5625. Expressed in reformulated form, the third ratio defined as the square root of a free flow area of the second pipe divided by the square root of a free flow area of the second separator is in the range of 0.05 to 0.75.

[0054] Preferably, a cross-sectional area of the second pipe denotes the free flow area of the second pipe. It is particularly preferred that the free flow area of the second pipe and/or the cross-sectional area of the second pipe are constant over the pipe length of the second pipe.

[0055] Preferably, a cross-sectional area of the second separator denotes the free flow area of the second separator. It is particularly preferred that the free flow area of the second separator and/or the cross-sectional area of the second separator are constant over the length of the second separator. The "and" cases are preferred.

[0056] Preferably, the cross-sectional area of the second pipe is rectangular and/or the cross-sectional area of the second separator is rectangular. It is particularly preferred that the cross-sectional area of the second pipe is round and/or the cross-sectional area of the second separator is round. The "and" cases are preferred.

[0057] The advantage is that a flow regime of the biphasic mixture flow in the second pipe can be adjusted. A stratified flow regime can advantageously be reached. By reaching a stratified flow regime, a clear difference between the second gas flow and the second liquid electrolyte flow in the second pipe appears. In particular, reaching a stratified flow regime in the second pipe can mean that the second gas flow and the second liquid electrolyte flow in the second pipe are spatially separated due to their density. The second gas flow flows on top of the second liquid electrolyte flow with a flat interface between the second gas flow and the second liquid electrolyte flow.

[0058] For this purpose, a flow velocity of the second gas flow and a flow velocity of the second liquid electrolyte flow in the second pipe can be reduced. Additionally, a turbulence of the second gas flow and a turbulence of the second liquid electrolyte flow in the second pipe can be reduced.

[0059] Advantage of the arrangement is that the separation efficiency of the second liquid electrolyte flow and the second gas flow can be increased and additionally, explosive gas mixtures in the arrangement are avoided. This is achieved in that the second liquid electrolyte flow and the second gas flow are not only separated from each other within the second separator, but partially already within the second pipe that leads to the second separator.

[0060] The first horizontal axis and the second horizontal axis can be arranged in any way with respect to each other. For example, the first horizontal axis and the second horizontal axis can be parallel to each other. In particular, they can coincide. However, they can also be spaced apart from each other.

[0061] In a preferred embodiment of the arrangement, the second pipe has a length that is at least equal to the square root of the free flow area of the second pipe. Preferably, the second pipe has a length that is at least four times the square root of the free flow area of the second pipe divided by the square root of pi. In the case the second pipe has a circular cross-section, this means that the second pipe has a length that is at least twice the diameter of the second pipe.

[0062] Advantage of the embodiment is that that a stratified flow regime in the second pipe can be obtained particularly well. In particular, the stratified flow regime can be obtained at least towards the second pipe end opening of the second pipe.

[0063] In a further preferred embodiment of the arrangement, the second pipe is cylindrical, wherein the first pipe end opening is opposite to the second pipe end opening. It is preferred, but not necessary that the first pipe end opening of the second pipe and the second pipe end opening of the second pipe are the same size. Advantage of the embodiment is that a stratified flow regime is achieved particularly well.

[0064] In a further preferred embodiment, the second pipe has an inner diameter, and the second separator has an inner diameter, and wherein a fourth ratio defined as the inner diameter of the second pipe divided by the inner diameter of the second separator is in the range of 0.05 to 0.75.

[0065] Preferably, the second separator is cylindrical.

[0066] Advantage of the embodiment is that the separation efficiency of second liquid electrolyte flow and the second gas flow can be increased and additionally, explosive gas mixtures in the arrangement are avoided.

[0067] In a further preferred embodiment of the arrangement based on the previous embodiment, the second pipe has a length that is at least equal to two times the inner diameter of the second pipe.

[0068] Advantage of the embodiment is that that a stratified flow regime in the second pipe can be obtained particularly well. In particular, the stratified flow regime can be obtained at least towards the second pipe end opening of the second pipe. Further advantage is that the length of the second separator can be particularly shortened.

[0069] In a further preferred embodiment of the arrangement, the second separator has a gas outlet, and the second separator has an electrolyte outlet. The gas outlet is arranged above the electrolyte outlet.

[0070] The second gas flow can be discharged from the second separator via the gas outlet. The second liquid electrolyte flow can be drained from the second separator via the electrolyte outlet. In particular, the second liquid

flow has a higher density than the second gas flow. Following this condition, it is advantageous to arrange the gas outlet above the electrolyte outlet. Preferably, the gas outlet and the electrolyte outlet are vertically distanced from each other as far as possible. This could mean that the gas outlet is arranged at the top of the second separator and the electrolyte outlet is arranged at the bottom of the second separator. Preferably, the gas outlet and the electrolyte outlet are arranged at the second end of the second separator. Advantage of the embodiment is that the second gas flow and the second electrolyte flow can be separated particularly easily.

[0071] In a further preferred embodiment of the arrangement, the second pipe is immediately connected to the inlet of the second separator. Advantage of the embodiment is that the overall length of the second separator is particularly shortened.

[0072] In a further preferred embodiment of the arrangement, the first pipe end opening of the first pipe is fluidly connected to the cathode side of the electrolysis stack. Preferably, the first pipe end opening of the second pipe is fluidly connected to the anode side of the electrolysis stack.

[0073] In a further preferred embodiment of the arrangement, the cathode side of the electrolysis stack is a source of the first gas flow and of the first liquid electrolyte flow. Preferably, the anode side of the electrolysis stack is a source of the second gas flow and of the second liquid electrolyte flow.

[0074] As a further aspect of the invention, a method to operate an arrangement configured as described is presented, wherein the method comprises the following steps:

- Generating a first biphasic flow within the electrolysis stack, wherein the first biphasic flow comprises the first liquid electrolyte flow and the first gas flow,
- Guiding the first biphasic flow through the first pipe to the first separator,
- Stratifying the first biphasic flow in the first pipe,
- Separating the stratified first biphasic flow in the first separator to the first gas flow and the first electrolyte flow,
- Recycling the first electrolyte flow to the electrolysis stack.

[0075] The described advantages and features of the arrangement are applicable and transferable to the method, and vice versa. The arrangement is preferably set up for operation according to the method. The method is preferably carried out with the arrangement.

[0076] In a preferred embodiment of the method, the method comprises the further steps:

- Generating a second biphasic flow within the electrolysis stack, wherein the second biphasic flow comprises the second liquid electrolyte flow and the second gas flow,
- Guiding the second biphasic flow through the second pipe to the second separator,
- Stratifying the second biphasic flow in the second pipe,
- Separating the stratified second biphasic flow in the second separator to the second gas flow and the second electrolyte flow,
- Recycling the second electrolyte flow to the electrolysis stack.

[0077] In a further preferred embodiment of the method, the Reynolds number of the first gas flow in the first pipe is in the range of 0.2 to 100, and the Reynolds number of the first liquid electrolyte flow in the first pipe is in the range of 2 to 100.

[0078] In the first pipe, the Reynolds number of the first gas flow and the Reynolds number of the first liquid electrolyte flow can be considered separately. In particular, the separate consideration of the first gas flow and the first liquid electrolyte flow can be feasible when the first liquid electrolyte flow and the first gas flow are stratified.

[0079] Preferably, the first gas flow and/or the first liquid electrolyte flow are laminar, at least before being injected for separation into the first separator.

[0080] In a further preferred embodiment of the method, the Reynolds number of the second gas flow in the second pipe is in the range of 0.2 to 100, and the Reynolds number of the second liquid electrolyte flow in the second pipe is in the range of 2 to 100.

[0081] In the second pipe, the Reynolds number of the second gas flow and the Reynolds number of the second liquid electrolyte flow can be considered separately. In particular, the separate consideration of the second gas flow and the second liquid electrolyte flow can be feasible when the second liquid electrolyte flow and the second gas flow are stratified.

[0082] Preferably, the second gas flow and/or the second liquid electrolyte flow are laminar, at least before being injected for separation in the second separator.

[0083] In a further preferred embodiment of the method, the first electrolyte flow in the first pipe comprises water, and the first gas flow in the first pipe comprises an electrolysis product. In particular, the first gas flow in the first pipe can comprise hydrogen. Preferably, the second electrolyte flow in the second pipe comprises water, and the second gas flow in the second pipe comprises an electrolysis product. In particular, the second gas flow in the second pipe can comprise oxygen.

[0084] In a preferred alternative embodiment of the

method, the recycled first liquid electrolyte flow volume of the first separator is in the range between 0.05 and 50 m³/h and/or the recycled second liquid electrolyte flow volume of the second separator is in the range between 0.05 and 50 m³/h. Preferably, the entire recycled liquid electrolyte flow volume is in the range between 0.1 and 100 m³/h, wherein the entire recycle liquid electrolyte flow comprises the recycled first liquid electrolyte flow volume of the first separator and the recycled second liquid electrolyte flow volume of the second separator. Advantage of the embodiment is that explosive gas mixtures in the arrangement are avoided.

[0085] In general, the advantages of the first pipe are applicable to the second pipe, and the advantages of the first separator are applicable to the second separator.

[0086] In the following the invention will be described with respect to the figures. The figures show two 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 schematic representation of an arrangement according to the invention,

Fig. 2: a schematic representation of a further arrangement according to the invention.

[0087] Figure 1 schematically shows an arrangement 1 for electrolysis, which comprises:

- an electrolysis stack 2 having an anode side 4 and a cathode side 3,
- a first separator 6.1 for separating a first gas flow 8.1 and a first liquid electrolyte flow 9.1,
- a first pipe 5.1, which is oriented along a first horizontal axis 12.1, and which has a first pipe end opening 10.1 and a second pipe end opening 11.1.

[0088] The first pipe end opening 10.1 of the first pipe 5.1 is fluidly connected to the electrolysis stack 2, wherein the second pipe end opening 11.1 of the first pipe 5.1 is fluidly connected to an inlet 13.1 of the first separator 6.1. A first ratio R_1 defined as a free flow area A_{P1} of the first pipe 5.1 divided by a free flow area A_{S1} of the first separator 6.1 is in the range of 0.002 to 0.6. The first

$$R_1 = \frac{A_{P1}}{A_{S1}}$$

ratio can be denoted as R_1 with $0.002 < R_1 < 0.6$. The first pipe 5.1 has a length L_{P1} that is at least equal to the square root of the free flow area A_{P1} of the first pipe 5.1.

[0089] The first separator 6.1 has a gas outlet 14.1 and the first separator 6.1 has an electrolyte outlet 15.1, wherein the gas outlet 14.1 is arranged above the electrolyte outlet 15.1. The first pipe 5.1 is immediately connected to the inlet 13.1 of the first separator 6.1.

[0090] The arrangement 1 further comprises:

- a second separator 6.2 for separating a second gas flow 8.2 and a second liquid electrolyte flow 9.2,
- a second pipe 5.2, which is oriented along a second horizontal axis 12.2, and which has a first pipe end opening 10.2 and a second pipe end opening 11.2.

[0091] The first pipe end opening 10.2 of the second pipe 5.2 is fluidly connected to the electrolysis stack 2, wherein the second pipe end opening 11.2 of the second pipe 5.2 is fluidly connected to an inlet 13.2 of the second separator 6.2. A third ratio R_3 defined as a free flow area A_{P2} of the second pipe 5.2 divided by a free flow area A_{S2} of the second separator 6.2 is in the range of 0.002 to 0.6.

$$R_3 = \frac{A_{P2}}{A_{S2}}$$

The third ratio can be denoted as R_3 with $0.002 < R_3 < 0.6$. The second pipe 5.2 has a length L_{P2} that is at least equal to the square root of the free flow area A_{P2} of the second pipe 5.2.

[0092] The second separator 6.2 has a gas outlet 14.2 and the second separator 6.2 has an electrolyte outlet 15.2, wherein the gas outlet 14.2 is arranged above the electrolyte outlet 15.2. The second pipe 5.2 is immediately connected to the inlet 13.2 of the second separator 6.2.

[0093] The first pipe end opening 10.1 of the first pipe 5.1 is fluidly connected to the cathode side 3 of the electrolysis stack 2 and the first pipe end opening 10.2 of the second pipe 5.2 is fluidly connected to the anode side 4 of the electrolysis stack 2.

[0094] The cathode side 3 of the electrolysis stack 2 is a source 7 of the first gas flow 8.1 and of the first liquid electrolyte flow 9.1. The anode side 4 of the electrolysis stack 2 is a further source of the second gas flow 8.2 and of the second liquid electrolyte flow 9.2.

[0095] To operate the arrangement 1 the following steps are conducted:

- Generating a first biphasic flow within the electrolysis stack 2, wherein the first biphasic flow comprises the first liquid electrolyte flow 9.1 and the first gas flow 8.1,
- Generating a second biphasic flow within the electrolysis stack 2, wherein the second biphasic flow comprises the second liquid electrolyte flow 9.2 and the second gas flow 8.2,
- Guiding the first biphasic flow through the first pipe 5.1 to the first separator 6.1,
- Guiding the second biphasic flow through the second pipe 5.2 to the second separator 6.2
- Stratifying the first biphasic flow in the first pipe 5.1,
- Stratifying the second biphasic flow in the second pipe 5.2,

- Separating the stratified first biphasic flow in the first separator 6.1 to the first gas flow 8.1 and the first electrolyte flow 9.1,
- Separating the stratified second biphasic flow in the second separator 6.2 to the second gas flow 8.2 and the second electrolyte flow 9.2,
- Recycling the first electrolyte flow 9.1 to the electrolysis stack 2, and
- Recycling the second electrolyte flow 9.2 to the electrolysis stack 2.

[0096] The first electrolyte flow 9.1 in the first pipe 5.1 comprises water, and the first gas flow 8.1 in the first pipe 5.1 comprises hydrogen as an electrolysis product. The second electrolyte flow 9.2 in the second pipe 5.2 comprises water, and the second gas flow 8.2 in the second pipe 5.2 comprises oxygen as an electrolysis product.

[0097] The Reynolds number Re_g of the first gas flow 8.1 in the first pipe 5.1 is in the range of 0.2 to 100, and the Reynolds number Re_l of the first liquid electrolyte flow 9.1 in the first pipe 5.1 is in the range of 2 to 100. The Reynolds number Re_g of the second gas flow 8.2 in the second pipe 5.2 is in the range of 0.2 to 100, and the Reynolds number Re_l of the second liquid electrolyte flow 9.2 in the second pipe 5.2 is in the range of 2 to 100.

[0098] The first electrolyte flow 9.1 leaving the first separator 6.1 and the second electrolyte flow 9.2 leaving the second separator 6.2 are mixed and pumped by a pump 17 to the electrolysis stack 2. Surplus heat of the first electrolyte flow 9.1 and of the second electrolyte flow 9.2 is dissipated by a heat exchanger 16 downstream to the pump 17.

[0099] According to the exemplary embodiment in Fig. 1, the separation efficiency of the first liquid electrolyte flow 9.1 and the first gas flow 8.1 can be increased and the separation efficiency of the second liquid electrolyte flow 9.2 and the second gas flow 8.2 can be increased. Additionally, explosive gas mixtures in the arrangement 1 are avoided.

[0100] Fig. 2 shows a further embodiment of the arrangement 1. With reference to Fig. 1, unless otherwise described, identical reference signs denote identical objects. Subsequently, the differences to Fig. 1 are denoted.

[0101] In the arrangement 1 in Fig. 2, the first pipe 5.1 is cylindrical, and the first pipe end opening 10.1 is opposite to the second pipe end opening 11.1. The first pipe 5.1 has an inner diameter d_{P1} , and the first separator 6.1 has an inner diameter d_{S1} . A second ratio R_2 defined as the inner diameter d_{P1} of the first pipe 5.1 divided by the inner diameter d_{S1} of the first separator 6.1 is in the range of 0.05 to 0.75. The second ratio can be denoted as

$R_2 = \frac{d_{P1}}{d_{S1}}$ with $0.05 < R_2 < 0.75$. The first pipe 5.1 has the length L_{P1} that is at least equal to two times the inner

diameter d_{P1} of the first pipe 5.1.

[0102] The second pipe 5.2 is cylindrical, and the first pipe end opening 10.2 is opposite to the second pipe end opening 11.2. The second pipe 5.2 has an inner diameter d_{P2} , and the second separator 6.2 has an inner diameter d_{S2} . A fourth ratio R_4 defined as the inner diameter d_{P2} of the second pipe 5.2 divided by the inner diameter d_{S2} of the second separator 6.2 is in the range of 0.05 to 0.75.

The fourth ratio can be denoted as $R_4 = \frac{d_{P2}}{d_{S2}}$ with $0.05 < R_4 < 0.75$. The second pipe 5.2 has the length L_{P2} that is at least equal to two times the inner diameter d_{P2} of the second pipe 5.2.

[0103] Due the exemplary embodiment in Fig. 2, the separation efficiency of first liquid electrolyte flow 9.1 and the first gas flow 8.1 can be increased and the separation efficiency of second liquid electrolyte flow 9.2 and the second gas flow 8.2 can be increased. Additionally, explosive gas mixtures in the arrangement 1 are avoided.

List of reference signs

[0104]

1	arrangement
2	electrolysis stack
3	cathode side
4	anode side
5.1	first pipe
5.2	second pipe
6.1	first separator
6.2	second separator
7	source of gas flow and electrolyte flow
8.1;	first gas flow
8.2	second gas flow
9.1	first electrolyte flow
9.2	second electrolyte flow
10.1; 10.2	first pipe end opening
11.1; 11.2	second pipe end opening
12.1	first horizontal axis
12.2	second horizontal axis
13.1; 13.2	inlet of the separator
14.1; 14.2	gas outlet of the separator
15.1; 15.2	electrolyte outlet of the separator
16	heat exchanger
17	pump

A_{P1}	free flow area of the first pipe
A_{P2}	free flow area of the second pipe
A_{S1}	free flow area of the first separator
A_{S2}	free flow area of the second separator
d_{P1}	inner diameter of the first pipe
d_{P2}	inner diameter of the second pipe
d_{S1}	inner diameter of the first separator
d_{S2}	inner diameter of the second separator
L_{P1}	length of the first pipe
L_{P2}	length of the second pipe

Claims

1. Arrangement (1) for electrolysis comprising:

- an electrolysis stack (2) having an anode side (4) and a cathode side (3),
- a first separator (6.1) for separating a first gas flow (8.1) and a first liquid electrolyte flow (9.1),
- a first pipe (5.1), which is oriented along a first horizontal axis (12.1), and which has a first pipe end opening (10.1) and a second pipe end opening (11.1),

wherein the first pipe end opening (10.1) of the first pipe (5.1) is fluidly connected to the electrolysis stack (2), wherein the second pipe end opening (11.1) of the first pipe (5.1) is fluidly connected to an inlet (13.1) of the first separator (6.1), and wherein a first ratio defined as a free flow area (A_{P1}) of the first pipe (5.1) divided by a free flow area (A_{S1}) of the first separator (6.1) is in the range of 0.002 to 0.6.

2. Arrangement (1) according to claim 1, wherein the first pipe (5.1) has a length (L_{P1}) that is at least equal to the square root of the free flow area (A_{P1}) of the first pipe (5.1).
3. Arrangement (1) according to one of the previous claims, wherein the first pipe (5.1) is cylindrical, and wherein the first pipe end opening (10.1) is opposite to the second pipe end opening (11.1).
4. Arrangement (1) according to one of the previous claims, wherein the first pipe (5.1) has an inner diameter (d_{P1}), and the first separator (6.1) has an inner diameter (d_{S1}), and wherein a second ratio defined as the inner diameter (d_{P1}) of the first pipe (5.1) divided by the inner diameter (d_{S1}) of the first separator (6.1) is in the range of 0.05 to 0.75.
5. Arrangement (1) according to claim 4, wherein the first pipe (5.1) has a length (L_{P1}) that is at least equal to two times the inner diameter (d_{P1}) of the first pipe (5.1).
6. Arrangement (1) according to one of the previous claims, wherein the first separator (6.1) has a gas outlet (14.1) and the first separator (6.1) has an electrolyte outlet (15.1), wherein the gas outlet (14.1) is arranged above the electrolyte outlet (15.1).
7. Arrangement (1) according to one of the previous claims, wherein the first pipe (5.1) is immediately connected to the inlet (13.1) of the first separator (6.1).
8. Arrangement (1) according to one of the previous claims, further comprising

- a second separator (6.2) for separating a second gas flow (8.2) and a second liquid electrolyte flow (9.2),
- a second pipe (5.2), which is oriented along a second horizontal axis (12.2), and which has a first pipe end opening (10.2) and a second pipe end opening (11.2),

wherein the first pipe end opening (10.2) of the second pipe (5.2) is fluidly connected to the electrolysis stack (2), wherein the second pipe end opening (11.2) of the second pipe (5.2) is fluidly connected to an inlet (13.2) of the second separator (6.2), and wherein a third ratio defined as a free flow area (A_{P2}) of the second pipe (5.2) divided by a free flow area (A_{S2}) of the second separator (6.2) is in the range of 0.002 to 0.6.

9. Arrangement (1) according to claim 8, wherein the first pipe end opening (10.1) of the first pipe (5.1) is fluidly connected to the cathode side (3) of the electrolysis stack (2) and the first pipe end opening (10.2) of the second pipe (5.2) is fluidly connected to the anode side (4) of the electrolysis stack (2).
10. Arrangement (1) according to one of the previous claims, wherein the cathode side (3) of the electrolysis stack (2) is a source (7) of the first gas flow (8.1) and of the first liquid electrolyte flow (9.1).
11. Method to operate an arrangement (1) according to one of claims 1 to 10, comprising the following steps:

Generating a first biphasic flow within the electrolysis stack (2), wherein the first biphasic flow comprises the first liquid electrolyte flow (9.1) and the first gas flow (8.1),
Guiding the first biphasic flow through the first pipe (5.1) to the first separator (6.1),
Stratifying the first biphasic flow in the first pipe (5.1),
Separating the stratified first biphasic flow in the first separator (6.1) to the first gas flow (8.1) and the first electrolyte flow (9.1),
Recycling the first electrolyte flow (9.1) to the electrolysis stack (2).

12. Method according to claim 11, wherein the Reynolds number of the first gas flow (8.1) in the first pipe (5.1) is in the range of 0.2 to 100, and wherein the Reynolds number of the first liquid electrolyte flow (9.1) in the first pipe (5.1) is in the range of 2 to 100.
13. Method according to one of the claims 11 to 12, wherein the first electrolyte flow (9.1) in the first pipe (5.1) comprises water, and wherein the first gas flow (8.1) in the first pipe (5.1) comprises an electrolysis product.

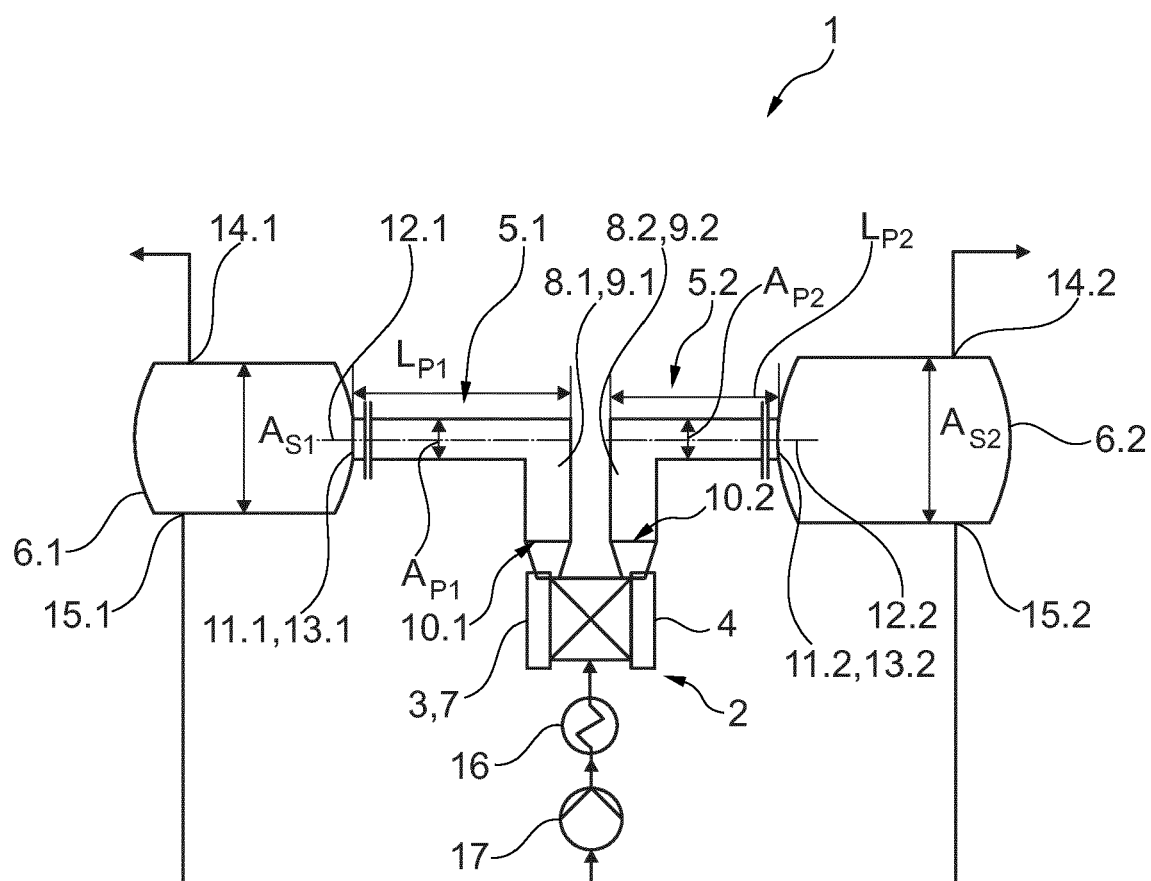


Fig. 1

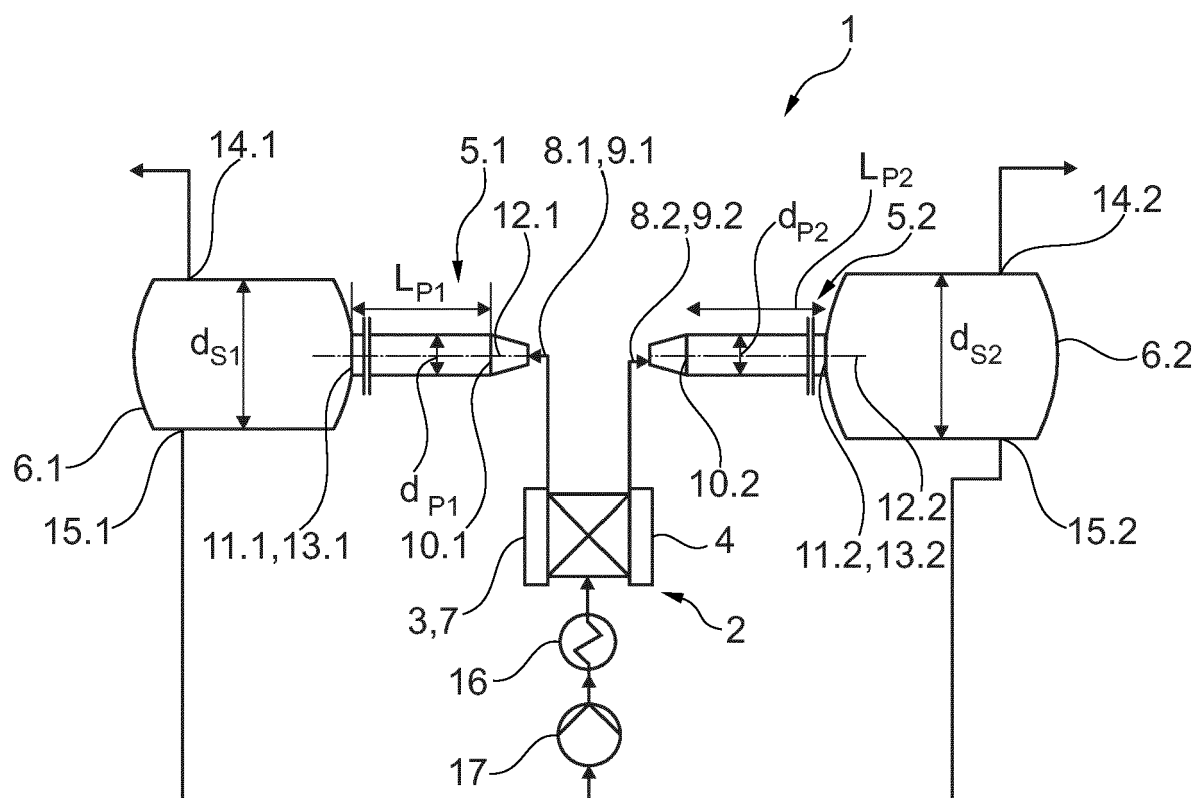


Fig. 2



EUROPEAN SEARCH REPORT

Application Number

EP 24 15 0671

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	JP 2013 063374 A (VANTEC KK) 11 April 2013 (2013-04-11)	1-13	INV. C25B1/04
Y	* paragraph [0026] - paragraph [0043]; claims 1-5; figures 1-6 * * paragraph [0055] * -----	8-10,12	C25B15/08
Y	WO 2023/232988 A1 (UNIV ANTWERPEN [BE]) 7 December 2023 (2023-12-07) * claims 1-18; figures 1,2, 8 * -----	12	
Y	CN 114 990 632 A (UNIV EAST CHINA SCIENCE & TECH) 2 September 2022 (2022-09-02) * claims 1-10; figures 1-2 * -----	8-10	
			TECHNICAL FIELDS SEARCHED (IPC)
			C25B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		19 August 2024	Teppo, Kirsi-Marja
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 24 15 0671

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

19-08-2024

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2013063374 A	11-04-2013	JP 6008482 B2	19-10-2016
		JP 2013063374 A	11-04-2013

WO 2023232988 A1	07-12-2023	NONE	

CN 114990632 A	02-09-2022	NONE	

15

20

25

30

35

40

45

50

55

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82