(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 573 626 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
12.03.1997 Bulletin 1997/11

(21) Application number: **92924495.2**

(22) Date of filing: **02.12.1992**

(51) Int. Cl.[6]: **B01F 3/04**, B01F 5/04

(86) International application number:
PCT/AU92/00645

(87) International publication number:
WO 93/10890 (10.06.1993 Gazette 1993/14)

(54) AERATION REACTOR

BELÜFTUNGSREAKTOR

REACTEUR D'AERATION

(84) Designated Contracting States:
AT BE DE DK ES FR GB SE

(30) Priority: **02.12.1991 AU 97/91**

(43) Date of publication of application:
15.12.1993 Bulletin 1993/50

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(56) References cited:

EP-A- 0 017 451	**WO-A-91/07099**
AU-A- 3 972 678	**AU-A- 7 364 274**
DE-A- 2 120 875	**DE-A- 3 010 351**
FR-A- 2 301 290	**GB-A- 1 405 264**
GB-A- 1 549 523	**US-A- 4 208 375**

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Description

Field of the Invention

The invention relates to a reactor for a two-phase or three-phase system.

The invention has particular application to the aeration of a fluid comprising a slurry of mineral particles with air or any other suitable oxygen-containing gas, as is required by way of example in aerobic bacterial leaching. However, the invention is not restricted to this application and extends to the aeration of any liquid-based systems such as gas/liquid, gas/liquid/solid, or gas/liquid/solid/microbial systems.

The invention has the advantages of enabling a fluid to be aerated with a gas at low energy usage and with high efficiency in terms of gas utilisation.

The term "aeration" is understood to mean herein the introduction of a gas or gases into a fluid.

Background of the Invention

Reactors for aeration of slurries have been in use for many years in the mining industry. The two major types of reactors are the Pachuca (or air agitated reactor) and the mechanically agitated reactor.

The Pachuca reactor was initially favoured due to its simplicity of construction and operation but gradually lost favour as reactor size increased. The loss of favour resulted from the large amounts of compressed air required for good mineral suspension. Also, the residence time of air in a Pachuca reactor is too short for efficient mass transfer and Pachuca reactors are prone to channelling of the air. Air agitation, in general, is inefficient because the bubble size for efficient agitation is too large for efficient mass transfer.

Mechanical agitation has become more widely used, particularly for large reactors, as impeller design has become more efficient and it has become evident that the extra capital cost was more than compensated for by the relatively lower energy required for agitation.

For efficient mass transfer of air to solution it is necessary to obtain a fine dispersion of bubbles in a well mixed system with the bubbles having a long residence time in the reactor. In practice this has been obtained by passing the air through a high shear turbine impeller or by introducing the air through a membrane or porous diffuser. Both these methods are energy intensive, because the air must be introduced at sufficient over-pressures to overcome the liquid pressure at the point of injection and to overcome the pressure drop across the injection opening, membrane or diffuser. Usually, the point of injection is at the bottom of the reactor and, in particular, in the case of aerating large vessels, one of the major costs is the capital and on-going energy costs to compress the air to the pressure required for injection. If the tanks are deeper than about 10 m it is necessary to install expensive, high pressure, compressors rather than air blowers. Additionally, the use of porous diffusers, or spargers, in reactors for slurries can lead to loss of operating time to unblock the diffusers.

In addition, mechanically agitated reactors become inefficient when large amounts of air are required, because the power required to disperse the air in the reactors becomes very large. Further, in the case of bacterial reactors, the shear forces present at the blade tips of high speed impellers can damage the bacteria.

In addition, particularly for gas/liquid/solid systems where it is important to maintain the solids in suspension, the power required to circulate the fluid in the aerator becomes a significant cost factor.

Summary of the Invention

According to the present invention a reactor (11) for introducing a gas into a liquid comprises a mixing tank (12) for the liquid, a partition means (13) for dividing the tank into at least two chambers (21,23) and for allowing the liquid to flow between the chambers (21,23) at a lower region and an upper region of the tank (12), a pump means (14) located in one of the chambers for circulating the liquid downwards in one chamber (21) and then upwards in the other chamber (23), an external circuit (6) for a side stream of the liquid from the tank comprising:

(a) a region of restricted cross-section for imparting a venturi effect to the liquid passing therethrough to create a region (3) of reduced pressure in the liquid;
(b) a means (2) for introducing the gas into the liquid in the region (3) of reduced pressure to aerate the liquid; and
(c) a means (19) for introducing the aerated liquid into the circulating liquid in the tank (12).

According to a preferred embodiment of the invention there is provided a reactor for introducing a gas into a liquid comprising a mixing tank for the liquid, a partition means for dividing the tank into at least two chambers and for allowing the liquid to flow between the chambers at a lower region and an upper region of the tank, a pump means located in one of the chambers for circulating the liquid downwards in one chamber and then upwards in the other chamber, a means for creating a region of reduced pressure in the liquid comprising a tubular member having a region of restricted

cross-section for imparting a venturi effect to the liquid passing through the tubular member whereby the velocity of the liquid increases and the pressure of the liquid decreases in the region of restricted cross-section, a means for introducing the gas into the liquid in the region of reduced pressure to aerate the liquid, and a means for introducing the aerated liquid into the circulating liquid in the tank.

It is preferred that the partition means comprises a draft tube adapted to be submerged in the liquid in the tank, the draft tube having an open upper end and an open lower end.

It is preferred particularly that the tank be cylindrical and the draft tube be located centrally in the tank to divide the tank into an inner chamber and an outer annular chamber.

It is preferred that the pump means be located in the draft tube.

It is preferred that the pump means comprises an axial flow pump.

It is preferred particularly that the axial flow pump comprises an impeller located in the draft tube.

It is preferred particularly that the means for introducing the aerated liquid into the circulating liquid in the tank be arranged to introduce the aerated liquid into the draft tube upstream of the impeller.

It is preferred that the means for introducing the gas into the liquid comprises a porous membrane, holes, or jets.

Aeration by use of a reactor according to the invention comprises circulating the liquid to be aerated by means of a pump means in a mixing tank having at least two chambers that are in fluid communication at upper and lower regions of the tank so that the liquid flows downwards in one chamber and upwards in the other chamber, creating a region of reduced pressure in a portion of the liquid, introducing the gas into the portion of the liquid in the region of reduced pressure to aerate the liquid, and introducing the aerated liquid into the circulating liquid in the tank.

Description of the Drawings

The invention is described further with reference to the accompanying drawings in which:

Figure 1 represents schematically a preferred embodiment of a reactor formed in accordance with the invention;

Figure 2 is a detailed schematic representation of the basic design of a venturi device for use in the reactor shown in Figure 1;

Figure 3 is a detailed schematic representation of a preferred embodiment of a venturi device for use in the reactor shown in Figure 1; and

Figure 4 is a graph of oxygen uptake and oxygen utilization versus air flow for the reactor shown in Figure 1 and a conventional air agitated reactor.

Detailed Description of the Invention

The preferred embodiment of the reactor of the invention is described herein in relation to the aeration of a slurry of a mineral and water with air. However, it is noted that the invention is not restricted to this application and extends to the aeration of any fluid with or without suspended solids.

The reactor 11 shown in Figure 1 comprises a mixing tank 12 containing the slurry, a vertical draft tube 13 submerged in the slurry, and a motor driven axial flow impeller 14 located in the draft tube 13 near the top thereof. The tank 12 may be of any suitable size. The draft tube 13 has open upper and lower ends 16, 18 and is located centrally in the mixing tank 12 to divide the mixing tank 12 into an inner chamber 21 and an outer annular chamber 23. In use, the impeller 14 induces flow of the slurry downwards in the draft tube 13 and then upwards in the outer annular chamber 23. The flow of the slurry is controlled so that the mineral particles are kept in suspension.

The reactor 11 further comprises an external circuit for withdrawing a portion of the slurry from the mixing tank 12, aerating the slurry, and returning the air-enriched slurry to the mixing tank 12. The external circuit comprises a recycle line 6, a pump 15 for pumping the slurry around the external circuit, and a venturi device 17 for aerating the slurry. The external circuit is arranged to withdraw slurry from an upper section of the mixing tank 12 and to return the air-enriched slurry to a location in the draft tube 13 above the impeller 14 to optimise mixing of the air-enriched slurry with the circulating slurry in the mixing tank 12. The external circuit comprises at least one re-entry nozzle 19 arranged to direct the air-enriched slurry down the draft tube 13.

Figure 2 illustrates the basic design features of the venturi device 17. With reference to the figure, the venturi device 17 comprises a tubular body 25 having an inlet end 41, an outlet end 43, and an intermediate throat 3 which defines a region of restricted cross-section in which there are holes 2 for introducing air for mixing with the slurry. As the slurry flows through the tubular body 25 in the direction indicated by the arrow A the flow rate increases as the slurry enters the throat 3 thereby creating a region of reduced pressure according Bernoulli's equation. As a consequence, in order to introduce air into the region of reduced pressure it is not necessary that the air be at high pressure and the air can

be introduced at low pressure or by natural aspiration. As the slurry flows from the throat 3 the slurry enters a region of increased cross-section 5 where the fluid velocity decreases and the pressure increases.

The region of increased cross-section 5 is shaped to give maximum energy recovery as the air-enriched slurry expands as it flows from the throat 3. Furthermore, the design and operating parameters of the venturi device 17 are selected to form air bubbles of optimal size for efficient oxygen mass transfer from the bubbles to the slurry. As a consequence, a minimal amount of air is required thereby reducing the operating costs. The design and operating parameters include slurry flow rate, air pressure, and the means of air injection into the slurry.

Figure 3 illustrates a preferred embodiment of the venturi device 17 for use with a 3,000 litre capacity mixing tank 12 and a 75 mm diameter recycle line 6. The throat 3 of the venturi device 17 comprises an entrance cone 45 of 25° and an exit cone 47 of 7° The diameter of the throat 3 is 25 mm and the diameter of the inlet and outlet ends 41, 43 is 75 mm. The holes 2 are located in the exit core 47 of throat 3 and are arranged in 3 circumferential rows spaced 5 mm apart with each row comprising 24 x 1 mm holes.

It will be clearly understood that the invention in its general aspects is not limited to the specific details referred to hereinabove.

The invention is now illustrated by way of reference to the following example.

A series of experiments was carried out on a conventional reactor comprising a 3,000 litre mixing tank stirred by an axial flow impeller and having air injection through a 1 mm drilled hole ring sparger mounted beneath the impeller and the preferred embodiment of the reactor of invention shown in Figure 1 comprising a 3,000 litre mixing tank stirred by an axial flow impeller located in a draft tube and having a venturi device returning aerated slurry to a location above the axial flow impeller.

The tanks contained 8% w/v slurry of a pyrite/pyrhotite tails which was being bacterially leached with Thiobacillus ferrooxidans.

The aeration performance of each tank was evaluated and the results are shown in Figure 4.

Figure 4 shows the relationships between:

(a) oxygen uptake in the slurry and air flow into the conventional reactor and the preferred embodiment of the reactor; and

(b) oxygen utilisation and air flow into the conventional reactor and the preferred embodiment of the reactor.

The term "oxygen uptake" refers to the amount of oxygen that was transferred to the liquor and therefore is a direct measure of the extent of aeration. The term "oxygen utilisation" refers to the amount of oxygen that was transferred to the liquor as a percentage of the total amount of oxygen introduced into the reactor and therefore is a direct measure of the efficiency of the aeration.

With reference to Figure 4, the term "air sparger" refers to the conventional reactor and the term "venturi aerator" refers to the preferred embodiment of the reactor.

The results in Figure 4 show that the aeration performance of the preferred embodiment of the reactor was significantly better than that of the conventional reactor. By way of particular example, with the preferred embodiment of the reactor it was possible to aerate the slurry with 150 mg O_2/litre of slurry/hour with an air flow of 60 l/min and an oxygen utilization of 50% whereas with the conventional reactor it was only possible to aerate the slurry with 150 mg O_2/litre of slurry/hour with a considerably higher air flow of 150 l/min and a significantly lower oxygen utilization of 20%.

The power requirements to aerate each reactor type with a given volume of air were monitored and scaled up to values representing the anticipated power requirements for aeration in a 1,000 m^3 tank. The results are shown in Table 1.

Table 1

Comparison of Aeration Power Requirements	
Tank Configuration	Aeration Power (Wh/m^3 of air)
Conventional Reactor with Air Sparger	80
Reactor of Invention with Draft Tube and Venturi	20

The results indicate significant power savings with the preferred embodiment of the reactor compared with the conventional reactor. Specifically, the results show that the energy required per m^3 of air delivered was four-fold lower for the preferred embodiment of the reactor than for the conventional reactor. On the basis of the results of the energy uti-

lization to achieve an O_2 uptake of 150 mg O_2/litre of slurry/hour discussed above, the energy required per m^3 of oxygen transferred was nine-fold lower for the preferred embodiment of the reactor than for the conventional reactor.

The preferred embodiment of the reactor of the invention has the following advantages over conventional reactor:

(i) The gas is supplied at low pressure or by natural aspiration, thereby eliminating the need for expensive high pressure gas compressors and reducing the reactor power requirements. Significantly, the agitator is used only to suspend the mineral particles and to circulate the aerated slurry.

(ii) The gas is injected or naturally aspirated at a point in the venturi device where the fluid velocity is high. This creates very small bubbles thus improving mass transfer of oxygen into solution. As a consequence, the operating costs are reduced because the air required for the reactor is minimised.

(iii) The aerated slurry is returned to the mixing tank above the impeller in a central draft tube at low pressure. As a consequence, operating costs are reduced because the pumping power required for circulating the slurry is minimised.

(iv) The capital cost of the reactor is minimised since there are less internal parts in the mixing tank. Furthermore, large reactors can be built leading to economies of scale.

(v) Maintenance costs and downtime are minimised since there are few parts to fail inside the mixing tank. Servicing the external components is simple since a single aeration device can be shut down for service without affecting the reactor's overall performance. Replacing a blocked aeration device can be done quickly with the minimum of interruption to the process.

(vi) The invention is suited for efficient gas supply and solids suspension in a gas-liquid-solid system or for efficient gas supply to a gas-liquid system. An example of the use of the invention is suspending and aerating a reacting slurry of mineral particles, as in bacterial leaching. Other uses include the bio-methanation of synthesis gas, aerobic digestion of sewage or other sludges and the production of synthetic rutile as in the Becher process. Its use, however, is not limited to these areas.

It is noted that whilst the impeller 14 is located near the top of the draft tube 13 in the preferred embodiment, the invention is not restricted to such an arrangement and the impeller 14 may be located at any suitable location along the length of the draft tube 13.

Claims

1. A reactor (11) for introducing a gas into a liquid comprising, a mixing tank (12) for the liquid, a partition means (13) for dividing the tank into at least two chambers (21,23) and for allowing the liquid to flow between the chambers (21,23) at a lower region and an upper region of the tank (12), a pump means (14) located in one of the chambers for circulating the liquid downwards in one chamber (21) and then upwards in the other chamber (23), an external circuit (6) for a side stream of the liquid from the tank (12) comprising:

   (a) a region of restricted cross-section (3) for imparting a venturi effect to the liquid passing therethrough to create a region (3) of reduced pressure in the liquid;
   (b) a means (2) for introducing the gas into the liquid in the region (3) of reduced pressure to aerate the liquid; and
   (c) a means (19) for introducing the aerated liquid into the circulating liquid in the tank (12).

2. A reactor according to claim 1, wherein said partition means comprises a draft tube (13) adapted to be submerged in the fluid in the tank (12), the draft tube having an open upper end (16) and an open lower end (18).

3. A reactor according to claim 2, wherein the tank (12) is cylindrical and the draft tube (13) is located centrally in the tank to divide the tank into an inner chamber (21) and an outer annular chamber (23).

4. A reactor according to any preceding claim, wherein the pump means comprises an axial flow pump (14).

5. A reactor according to claim 4, wherein the axial flow pump (14) is located in the draft tube (13).

6. A reactor according to claim 4 or claim 5, wherein the axial flow pump comprises an impeller.

7. A reactor according to claim 6, wherein the means (19) for introducing the aerated liquid into the circulating liquid in the tank is arranged to introduce the aerated liquid into the draft tube (13) upstream of the impeller (14).

8. A reactor according to any preceding claim, wherein the means for introducing the gas into the liquid in the region (3) of reduced pressure comprises a porous membrane, holes, or jets.

9. A reactor according to any preceding claim, wherein the means for creating the region of reduced pressure in the liquid comprises a tubular member having a region of restricted cross-section for imparting a venturi effect to the liquid passing therethrough whereby the velocity of the liquid increases and the pressure of the liquid decreases in the region of restricted cross-section.

Patentansprüche

1. Reaktor (11) für die Einführung von Gas in eine Flüssigkeit, umfassend einen Mischbehälter (12) für die Flüssigkeit, eine Trenneinrichtung (13), damit der Behälter in mindestens zwei Kammern (21,23) unterteilt wird und die Flüssigkeit zwischen den Kammern (21,23) im unteren Bereich und im oberen Bereich des Behälters (12) fließen kann, eine Pumpeinrichtung (14), die in einer der Kammern angeordnet ist, damit die Flüssigkeit in einer Kammer (21) nach unten und dann in der anderen Kammer (23) nach oben zirkuliert, einen externen Kreis (6) für einen Nebenstrom der Flüssigkeit aus dem Behälter (12), umfassend:

   (a) einen Bereich mit eingeschränktem Querschnitt (3), damit die hindurchströmende Flüssigkeit einen Venturieffekt erhält, wodurch in der Flüssigkeit ein Bereich (3) mit reduziertem Druck erzeugt wird;

   (b) eine Einrichtung (2) zum Einführem von Gas in die Flüssigkeit im Bereich (3) mit reduziertem Druck, wodurch die Flüssigkeit belüftet wird; und

   (c) eine Einrichtung (19) zum Einführen der belüfteten Flüssigkeit in die zirkulierende Flüssigkeit im Behälter (12).

2. Reaktor nach Anspruch 1, wobei die Trenneinrichtung ein Einzugsrohr (13) umfaßt, das dem Eintauchen in das Fluid im Behälter (12) dient, wobei das Einzugsrohr ein offenes oberes Ende (16) und ein offenes unteres Ende (18) aufweist.

3. Reaktor nach Anspruch 2, wobei der Behälter (12) zylindrisch ist und das Einzugsrohr (13) mittig im Behälter angeordnet ist, wodurch der Behälter in eine innere Kammer (21) und eine äußere ringförmige Kammer (23) unterteilt wird.

4. Reaktor nach einem der vorstehenden Ansprüche, wobei die Pumpeinrichtung eine Pumpe (14) mit Axialströmung umfaßt.

5. Reaktor nach Anspruch 4, wobei die Pumpe (14) mit Axialströmung im Einzugsrohr (13) angeordnet ist.

6. Reaktor nach Anspruch 4 oder Anspruch 5, wobei die Pumpe mit Axialströmung ein Flügelrad umfaßt.

7. Reaktor nach Anspruch 6, wobei die Einrichtung (19) zum Einführen der belüfteten Flüssigkeit in die zirkulierende Flüssigkeit im Behälter so angeordnet ist, daß die belüftete Flüssigkeit stromaufwärts des Flügelrades (14) in das Einzugsrohr (13) eingeführt wird.

8. Reaktor nach einem der vorstehenden Ansprüche, wobei die Einrichtung zum Einführen des Gases in die Flüssigkeit im Bereich (3) mit reduziertem Druck eine poröse Membran, Löcher oder Düsen umfaßt.

9. Reaktor nach einem der vorstehenden Ansprüche, wobei die Einrichtung zur Erzeugung des Bereiches mit reduziertem Druck in der Flüssigkeit ein rohrförmiges Teil umfaßt, das einen Bereich mit eingeschränktem Querschnitt aufweist, damit der hindurchströmenden Flüssigkeit ein Venturieffekt verliehen wird, wodurch im Bereich mit eingeschränktem Querschnitt die Geschwindigkeit der Flüssigkeit zunimmt und der Druck der Flüssigkeit abnimmt.

Revendications

1. Réacteur (11) pour introduire un gaz dans un liquide, comprenant une cuve de mélange (12) pour le liquide, un

moyen de séparation (13) pour diviser la cuve en au moins deux chambres (21,23) et pour permettre au liquide de s'écouler entre les chambres (21,23) dans une région inférieure et une région supérieure de la cuve (12), un moyen de pompage (14) placé dans une des chambres pour faire circuler le liquide vers le bas dans une chambre (21) puis vers le haut dans l'autre chambre (23), un circuit extérieur (6) pour une circulation secondaire du liquide à partir de la cuve (12) comportant :

(a) une région de section transversale réduite (3) pour communiquer un effet de venturi au liquide traversant cette région, afin de créer une région (3) de pression réduite dans le liquide ;
(b) un moyen (2) d'introduction du gaz dans le liquide dans la région (3) de pression réduite, afin d'aérer le liquide ; et
(c) un moyen (19) d'introduction du liquide aéré dans le liquide en circulation dans la cuve (12).

2. Réacteur suivant la revendication 1, dans lequel ledit moyen de séparation comprend un tube de cheminée prévu pour être submergé dans le fluide dans la cuve (12), le tube de cheminée ayant une extrémité supérieure ouverte (16) et une extrémité inférieure ouverte (18).

3. Réacteur suivant la revendication 2, dans lequel la cuve (12) est cylindrique et le tube de cheminée (13) est placé centralement dans la cuve de manière à diviser la cuve en une chambre intérieure (21) et une chambre annulaire extérieure (23).

4. Réacteur suivant une quelconque des revendications précédentes, dans lequel le moyen de pompage comprend une pompe à flux axial (14).

5. Réacteur suivant la revendication 4, dans lequel la pompe à flux axial (14) est placée dans le tube de cheminée (13).

6. Réacteur suivant la revendication 4 ou la revendication 5, dans lequel la pompe à flux axial comprend une roue d'impulsion.

7. Réacteur suivant la revendication 6, dans lequel le moyen (19) pour l'introduction du liquide aéré dans le liquide en circulation dans la cuve est agencé de manière à introduire le liquide aéré dans le tube de cheminée (13) en amont de la roue d'impulsion (14).

8. Réacteur suivant une quelconque des revendications précédentes, dans lequel le moyen d'introduction du gaz dans le liquide dans la région (3) de pression réduite comprend une membrane poreuse, des trous ou des jets.

9. Réacteur suivant une quelconque des revendications précédentes, dans lequel le moyen de création de la région de pression réduite dans le liquide comprend un élément tubulaire ayant une région de section transversale réduite pour communiquer un effet de venturi au liquide traversant cette région, de sorte que la vitesse du liquide augmente et que la pression du liquide diminue dans la région de section transversale réduite.

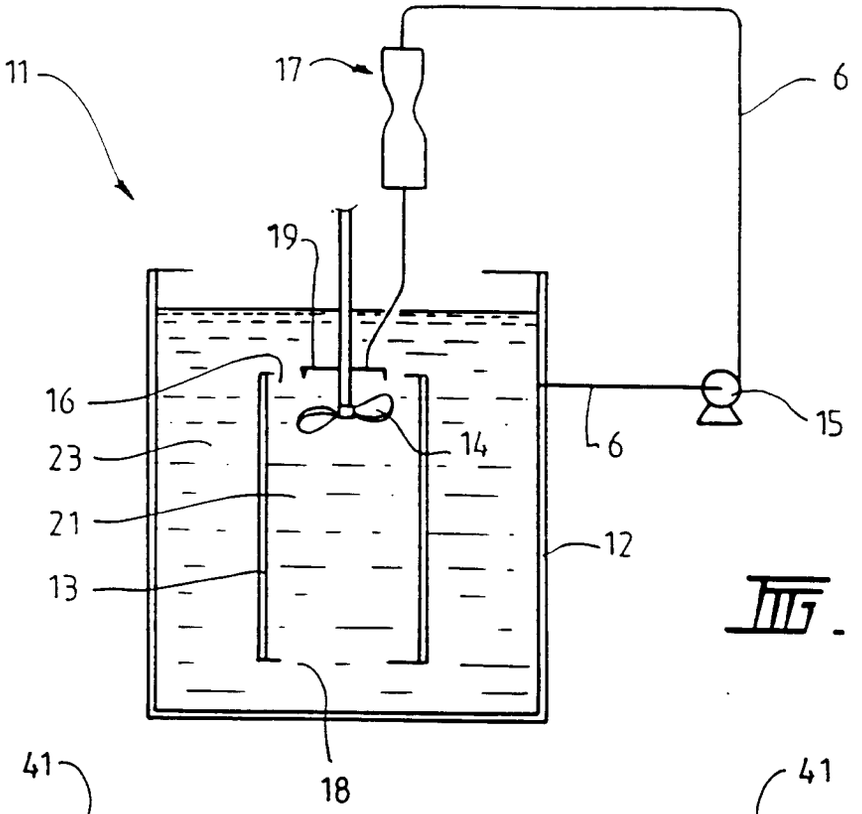


FIG. 1

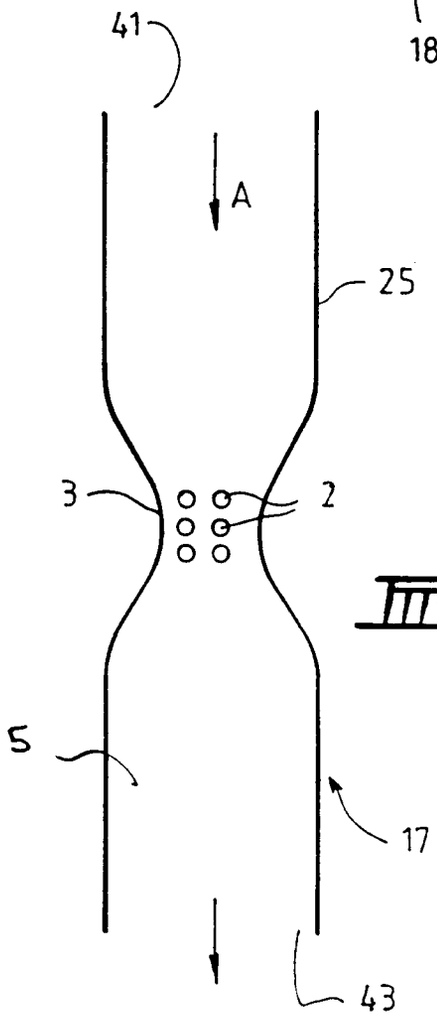


FIG. 2.

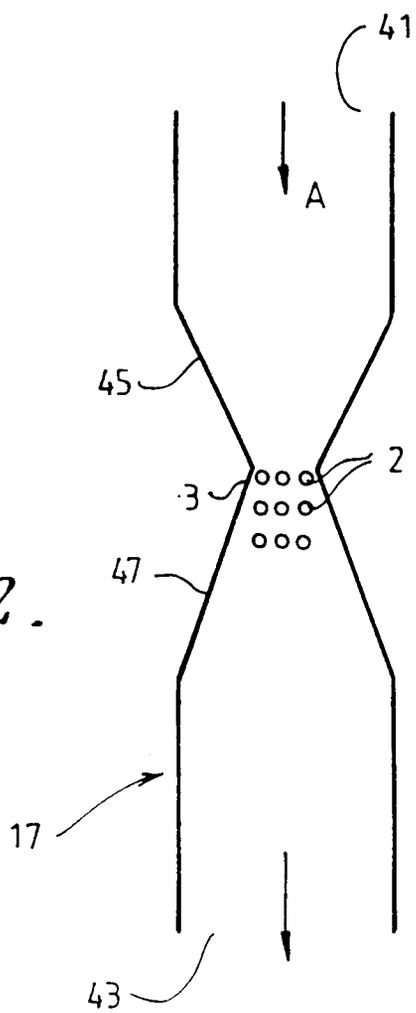


FIG. 3.

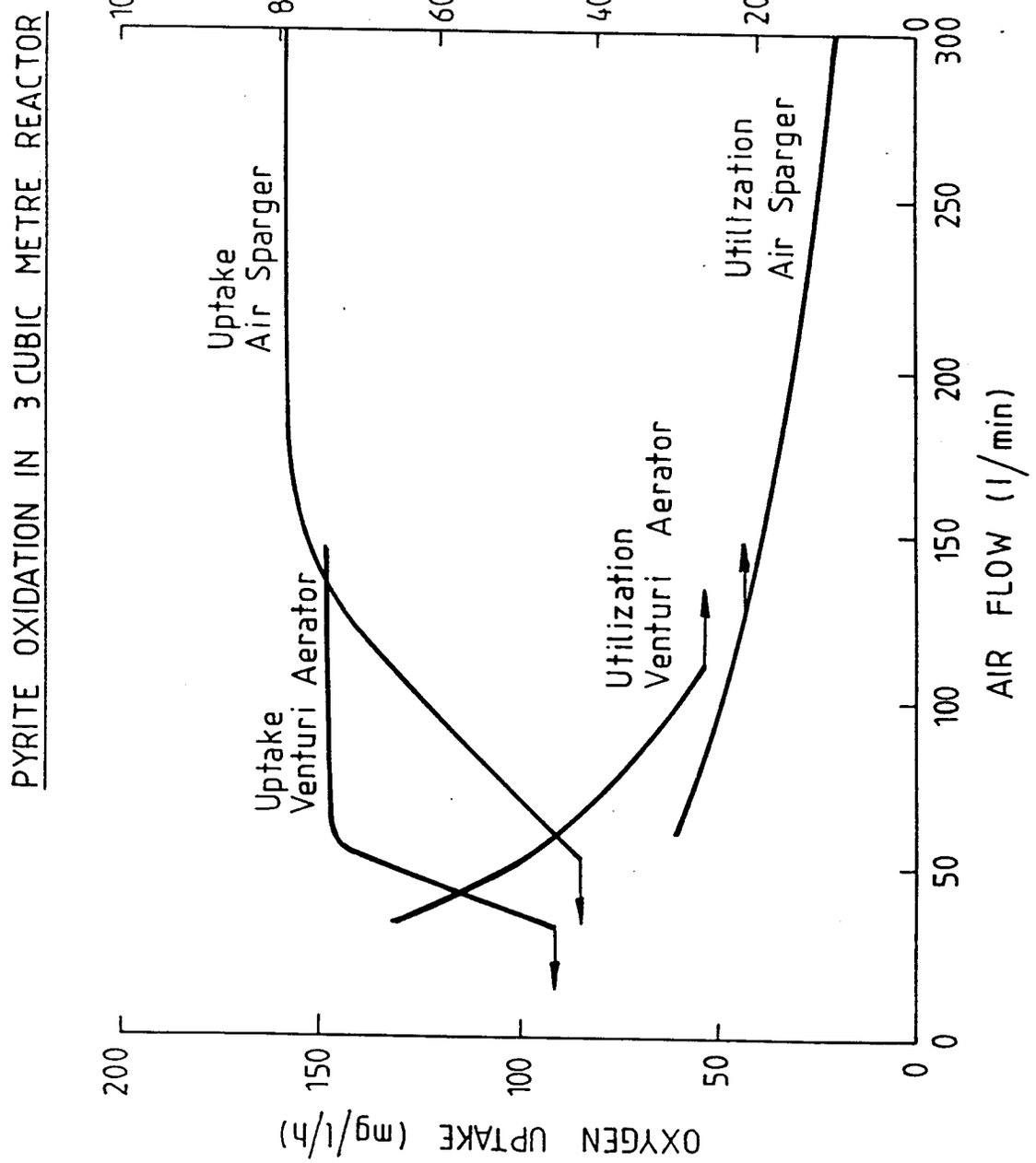

PYRITE OXIDATION IN 3 CUBIC METRE REACTOR
OXYGEN UPTAKE (mg/l/h)
OXYGEN UTILIZATION (%)
AIR FLOW (l/min)
Uptake Air Sparger
Uptake Venturi Aerator
Utilization Venturi Aerator
Utilization Air Sparger
0
50
100
150
200
0
20
40
60
80
100
0
50
100
150
200
250
300

FIG. 4.