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(56) Related Art
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US 4648888

DESCRIPTIVE ABSTRACT

PORTABLE OXYGEN CONCENTRATOR

IN THE NAMES OF: AIR LIQUIDE, SOCIETE ANONYME POUR L'ETUDE ET L'EXPLOITATION DES PROCEDES GEORGES CLAUDE and
AIR LIQUIDE SANTE (INTERNATIONAL)
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The invention relates to an oxygen concentrator portable by a patient, permitting producing a flow of gas containing 50% to 95% of oxygen from air, comprising air compression means, means for gas separation by adsorption with pressure variations, and electrical energy storage means keeping its charge for at least 30 minutes, said concentrator having a total weight less than 10 kg. Preferably, the gas separation means are a PSA system using a zeolite X exchanged with lithium, as the adsorbent.

Figure 1

AUSTRALIA

Patents Act

COMPLETE SPECIFICATION
(ORIGINAL)

Class Int. Class

Application Number:
Lodged:

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Name of Applicant:

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Invention Title:

PORTABLE OXYGEN CONCENTRATOR

Our Ref : 643167
POF Code: 1290/329618, 43509

The following statement is a full description of this invention, including the best method of performing it known to applicant(s):

6008q

The invention relates to a portable oxygen concentrator usable in oxygen therapy.

Oxygen concentrators using the PSA (Pressure Swing Adsorption) technique are at present very widely used for household oxygen therapy. Nevertheless, their design has a major drawback namely, the lack of portability.

Thus, the existing concentrators require a source of electricity and are moreover too heavy to be transported or carried by the patient.

However, a certain number of patients using oxygen therapy would like to live as "normal" a life as possible, which requires in particular to be able to walk or move more easily.

To give these patients a solution permitting them to make short trips, the documents WO-A-98/58219 and U.S. Patent 5,893,275 propose combining the PSA type concentrator with a liquefier, so as to fill a Dewar (receptacle) that the patient can carry. This solution is in fact more complicated than it appears. Thus, the Dewar for storing the oxygen must be periodically reheated to eliminate any trace of hydrocarbons and water. On the other hand, the adjustment of the liquefaction temperature must be precise so as to avoid at the

outset of vaporization for use by the patient, that the initial gas will have a high nitrogen content.

Another solution proposed in U.S. Patent 5,858,062 is to compress a portion of the oxygen leaving the PSA type concentrator to fill a portable cylinder. But this is costly solution because it is based on the use of an oxygen compressor, and less satisfactory from the point of view of safety, because the patient must manipulate oxygen under pressure.

The above discussion of the background to the invention herein is included to explain the context of the invention. This is not to be taken as an admission that any of the material referred to was published, known or part of the common general knowledge in Australia as at the priority date of any of the claims.

It is an object of the present invention to provide an oxygen concentrator which overcomes or at least alleviates one or more disadvantages of the prior art.

According to the present invention there is provided an oxygen concentrator portable by a patient and permitting production of a gas flow containing from 50% to 95% of oxygen from air, including:

- air compression means,
- means for separating gas by adsorption with pressure variation, and
- electrical energy accumulating means having a charged life of at least 30 minutes,
- said concentrator having a total weight less than 10 kg, and
- the weight of the compression means (Mcomp), the weight of the gas separation means (Msieve) and the weight of the energy accumulating means (Mbattery) being such that:

$$0.5 < \frac{Mcomp}{Qp} < 3$$

$$0.15 < \frac{Mbattery}{Qp} < 2$$

$$0.05 < \frac{Msieve}{Qp} < 1$$

wherein Qp is the flow rate for the production of oxygen by the concentrator (in l/min) and the weights Mcomp, Mbattery and Msieve are expressed in kg.

The present invention also provides an oxygen concentrator portable by a patient and permitting production of a gas flow containing 50% to 95% of oxygen from air, including:

- air compression means to compress the air to a pressure comprised between 1 and 5 bars,
- means for separating gas by adsorption with pressure variation, including several adsorbers each containing one or several adsorbents and operating according to PSA cycles, the duration at each production cycle being less than 30 seconds and a: least one adsorbent being a zeolite exchanged with at least one metallic cation selected from lithium, calcium, zinc, copper and their combinations,
- electrical energy accumulating means having a charge life of at least 30 minutes,
- said concentrator having a total weight less than 10 kg, and
- the weight of the compression means (Mcomp), the weight of the gas separation means (Msieve) and the weight of the energy accumulating means (Mbattery) being such that:

$$0.5 < \frac{Mcomp}{Qp} < 3$$

$$0.15 < \frac{Mbattery}{Qp} < 2$$

$$0.05 < \frac{Msieve}{Qp} < 1$$

wherein Qp is the flow rate of oxygen produced by the concentrator in l/min) and the weights Mcomp, Mbattery and Msieve are expressed in kg,

- said air compression means, said means for separating gas by adsorption and said electrical energy accumulating means being disposed within at least one housing,
- said housing moreover including means for controlling or adjusting the operation of the concentrator and at least one system of securing or carrying the concentrator.

An advantage, therefore, of the present invention is that it provides to patients desiring to have real mobility, an alternative solution that is more simple and more satisfactory as to safety, which is to say improving the known solutions of the prior art.

Accordingly, there is provided an oxygen concentrator portable by a patient, permitting the production of a gaseous flow containing 50% to 95% oxygen from air, comprising:

- air compression means to compress the air to a pressure greater than atmospheric pressure (1 bar),
- means for separating gas by adsorption with pressure variations to separate the air compressed by the air compression means and to produce a gas enriched in oxygen, and
- electrical energy accumulating means having a charged life of at least 30 minutes permitting storing and supplying or restoring electricity,
- said concentrator having a total weight less than 10 kg, and
- the weight of the compression means (Mcomp), the weight of the gas separation means (Msieve) and the weight of the energy accumulating means (Mbattery) being such that:

$$0.5 < \frac{Mcomp}{Qp} < 3$$

$$0.15 < \frac{Mbattery}{Qp} < 2$$

$$0.05 < \frac{Msieve}{Qp} < 1$$

wherein Qp is the flow rate of oxygen produced by the concentrator (in l/min) and the weights Mcomp, Mbattery and Msieve are expressed in kg.

Accordingly, there is also provided an oxygen concentrator portable by a patient, permitting producing a gaseous flow containing 50% to 95% of oxygen from air comprising:

- air compression means to compress the air to a pressure comprised between 1 and 5 bars,

- means for separating gas by adsorption, with pressure variations, comprising several adsorbers each comprising one or several adsorbents operating according to PSA cycles, the duration of each production cycle being less than 30 seconds and at least one adsorbent being a zeolite exchanged with at least one metallic cation selected from lithium, calcium, zinc, copper and their combinations,

- electrical energy accumulation means having a charged life of at least 30 minutes,

- said concentrator having a total weight less than 10 kg, and

- the weight of the compression means (Mcomp), the weight of the gas separation means (Mpsa) and the weight of the energy accumulation means (Mbattery) being such that:

$$0.5 < \frac{Mcomp}{Qp} < 3$$

$$0.15 < \frac{Mbattery}{Qp} < 2$$

$$0.05 < \frac{Msieve}{Qp} < 1$$

wherein Qp is the flow rate of oxygen production by the concentrator (in l/min) and the masees Mcomp, Mbattery and Msieve are expressed in kg,

- said air compression means, said means for separating gas by adsorption and said electric energy accumulating means being disposed within at least one housing,

- said housing comprising moreover means for controlling or adjusting the operation of the concentrator and at least one system for fastening or carrying the concentrator.

As the case may be, the concentrator of the invention can comprise one or several of the following characteristics:

- Qp is comprised between 0.5 and 4 l/min, preferably between 0.5 and 2 l/min.

- the ratio (Mcomp/Qp) is comprised between 0.5 and 2 kg/(l/min).

- the ratio (Mbattery/Qp) is comprised between 0.15 and 1.2 kg/(l/min).

- the ratio (Msieve/Qp) is comprised between 0.05 and 0.8 kg/(l/min).

- Mcomp + Mbattery + Msieve $\leq$ 8 kg, preferably Mcomp + Mbattery + Msieve $\leq$5 kg.

- the gas separation means comprise several adsorbers each containing one or several adsorbents and operating according to PSA cycles, preferably the duration of each production cycle is less than 30 seconds, preferably less than 20 seconds.

- the adsorbent has a granulometry less than 1 mm and/or comprises particles of zeolite X exchanged with at least one metallic cation selected from lithium, calcium, zinc, copper and their combinations, preferably zeolite X having a ratio Si/Al of about 1 to 1.25 and exchanged by at least 80% with lithium cations.

- the compression means are adapted or controlled to compress air at a pressure comprised between 1 and 5 bars, preferably between 2.5 and 3.5 bars.

- it comprises means for adjusting the temperature permitting adjusting the temperature of the air supply and/or of the adsorbers, to a value comprised between 10 and 60°C.

- the controller adjustment means of the operation of the concentrator comprise at least one start/stop means to start or stop the operation of the concentrator, preferably the start/stop means comprises an operating button or a control member actuable by the operator.

- the system of securing or carrying the concentrator comprises at least one carrying handle and/or at least one shoulder strap or a belt and/or at least one system of suspending from the belt.

- it comprises adjustment means for the flow rate of the gas to be produced by the means for separating gas by adsorption.

The present invention will now be better understood from the following detailed description given with reference to the accompanying drawings.

Contrary to what is said in WO-A-98/58219, the inventors of the present invention have shown that it is in fact possible to produce a really portable concentrator, by combining a certain number of technical advances which will be described below, namely a short production cycle, a small adsorbent granulometry, a "top grade" adsorbent, and the use of a system permitting reducing the flow rate to be produced by the concentrator whilst satisfying the oxygen needs of the patient.

It thus follows that an O_2 concentrator should be considered as portable if the two following conditions are satisfied, namely a weight m less than 10 kg, preferably less than 7 kg, and if it can operate on batteries, preferably rechargeable, having a charged life of at least 30 minutes, preferably at least one hour and more preferably at least two hours.

However, the total weight (MTW) of a PSA concentrator depends on the flow rate produced and the performance of the cycle:

- the yield η = O_2 produced/O_2 entering
- productivity per cycle Pcy = O_2 produced/cycle/m^3 of adsorbent
- cycle time Tcy = duration of a production cycle (in seconds).

Of course it also depends on the "mass performances" of the different components, for example the ratio between the weight of the compressor and the flow rate of air that it compresses.

The adjustment of a portable concentrator thus passes through a step of establishing the relationships between the performance of the PSA and the weight of the different components. The efficiency of the system will be measured by the weight necessary to produce 1l/min of oxygen. The system will be lighter the lower this ratio is and/or the lower the required flow rate of oxygen will be.

The principal components whose weight must be reduced are the air compressor, the adsorbent and the battery or the means for accumulating electrical current that are used.

Of course there are other components of the apparatus (external housing, adsorbents of the PSA system, internal tubing, valves...) but their weight is low, or even negligible, relative to that of the principal constituents.

Air compressor

The flow rate of air (Qa) that is to be supplied by the compressor is

$$Q_a = \frac{Q_p}{\eta \times 0.21}$$

in which Qp is the flow rate of produced oxygen (in l/min)

η is the yield defined above.

However, the best available compressors have a "mass efficiency" comprised between 1 kg for 5 l/min and 1 kg for 10 l/min. These values will therefore permit tracing two curves permitting enclosing the ratio:

Compressor weight/Flow rate of oxygen produced as a function of yield.

These curves are schematically shown in Figure 1.

Having the curves of Figure 1 and knowing that the yields obtained for a PSA cycle are typically comprised between 30 and 60%, there can be established the following inequality: $0.5 < Mcomp/Qp < 3$ kg (in kg/(l/min))

Battery (Reference 8 in Figure 5)

By analogy, the specific energy Es (in KWh/l of produced oxygen) of a PSA system can be expressed by the following relation:

$$E_s = \frac{k}{\eta * 0.21} \times \log\left(\frac{Ph}{Patm}\right)$$

wherein Ph is the high pressure of the cycle (in bars)

k is comprised between 0.11 and 0.15 according to the compressor

Patm is the atmospheric pressure (1 bar)

For a charged life of 2 hours, the necessary energy (in watts) is therefore expressed by the following relationship:

$$E = \frac{k}{\eta \times 0.21} \times Q_p \times 120 \times \log(Ph / Patm)$$

The high pressure of a PSA system being conventionally comprised between 2.5 and 3.5 bars, and the mass efficiency of the best batteries between 1 kg for 100 watts and 1 kg for 300 watts, there can again be traced two curves (shown in Figure 2) permitting enclosing the weight ratio battery/O2 flow rate, as a function of yield

There is obtained the following inequality:

$0.15 < Mbattery/Qp < 2$ (expressed in kg/(l/min))

Weight of the adsorbent of the PSA

Similarly, the weight of the adsorbent (Mads) is given by the following relation:

$$Mads = \frac{T_{cy} \times Q_p \times \rho_{ads}}{P_{cy}}$$

wherein ρ_{ads} is the weight per volume of the adsorbent, typically comprised between 0.5 and 0.7 kg/l. Tcy and Pcy are as given above.

The productivity per cycle typically obtained in a PSA cycle is comprised between 0.2 and 0.5 Nl/h/l. The weight of the adsorbent is directly proportional to the cycle time. The reduction of the cycle time can be achieved by a reduction of granulometry of the adsorbent to improve the adsorption kinesis. The cycle time of the medical concentrators is in general less than 25 s thanks to the use of an adsorbent whose mean granulometry is less than 1 mm. They can decrease to several seconds, as indicated by U.S. Patent 5,827,358.

There are again obtained two curves permitting enclosing the ratio Mads/O_2 flow rate produced as a function of the productivity of the PSA (productivity per cycle), as shown in Figure 3.

From this there is obtained the following inequality:

$$0.05 < Msieve/Qp < 1 \text{ (expressed in kg/(l/min))}$$

The rest of the material permitting producing the concentrator has a weight that is relatively less dependent on

the production flow rate and can be estimated to be 1 or 2 kg at the most.

The curves of Figures 1 to 3 show three ways of reducing the weight of a concentrator:

- reducing the required oxygen flow rate Qp
- increasing the mass performance of the components: compressor, battery...
- increasing the performance of the PSA process

The increase of the mass performance of the components is up to the manufacturers. In the present invention, it will suffice to choose components falling within the weight limits described above.

The reduction of the mean required flow rate Qp, to satisfy the oxygen needs of the patient, can be achieved by preferentially adding a system with an economizing valve, permitting delivering oxygen to the patient in a manner synchronized with breathing, and hence to divide the necessary oxygen production of the concentrator by a factor comprised between 1.5 and 6, preferably comprised between 2 and 4.

The usual prescription of gaseous oxygen for a patient undergoing oxygen therapy is comprised between 3 and 6 l/min. The use of such an economizing valve therefore permits reducing the mean flow rate of oxygen that has to be produced by the concentrator, to a value comprised between 0.5 and 4 l/min, preferably between 0.5 and 2 l/min.

The increase of performance of the PSA process is obtained by:

- use of a high quality adsorbent, preferably a zeolite X exchanged with lithium, permitting obtaining a yield greater than 45% and a productivity per cycle greater than 0.3 Nm^3/h,

- cycle time less than 20 s, preferably less than 15 s.

In this case, the preceding inequalities thus become:

$0.5 < Mcomp/Qp < 2$ (kg/(l/min)

$0.1 < Mbattery/Qp < 1.2$ (kg/(l/min)

$0.05 < Msieve/Qp < 0.8$ (kg/(l/min)

Under these conditions, it will be seen that the sum of the weights of the different components will be less than 8 kg for mean flow rate values up to 2 l/min.

Generally speaking, as shown in Figure 5, a portable concentrator 1 according to the invention has a housing 2 of a size and weight permitting the patient 3 to carry it while walking.

Possible systems for securing or carrying the concentrator 1 by the patient 3 are a handle 4 and/or a shoulder strap 5, provided on the concentrator 1 directly or on a bag dimensioned for this purpose, which permit protecting it for all outside uses.

The housing 2 is stable and can rest on any flat surface. It preferably has:

- an air outlet enriched in O_2, which can be connected to the administration means 6 of the gas to the patient 3;

- a start/stop button 9;

- an adjustment device 7 for the production flow rate of air enriched in O_2;

- a screen 10 and/or another system for visualization (luminous signals for example) permitting informing the patient or any other person, of the available adjustments as well as the potential risks and/or misfunctions (residual charge of the battery, misfunction of the compressor, for example);

- information labels guaranteeing the quality of the material and if desired the recommendations for its maintenance in good operating condition.

Figure 4 shows schematically the principle of operation of concentrator 1 according to the invention, comprising an external housing 2 in which are included one or more ambient air inlets 14 (systems of inlets for example) permitting supplying the compression means 10 with gas, and if desired generating an air circulation in the housing 2, gas compression means 10, gas separation means by adsorption with pressure variation (PSA) comprising several adsorbers 11, 12 enclosing adsorbent particles, electrical energy accumulating means 8, a storage 13 for storing air enriched in produced oxygen, and means 6 for supplying air enriched in produced oxygen to the respiratory tract of the patient 3.

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Moreover, to the principal elements constituting the concentrator schematically shown in Figure 4, can be added:

- one or several filtration means (dust, antibacterial...) for ambient air and/or air enriched in O_2;
- an electronic card for controlling the different components and their alarms;
- a system for soundproofing the assembly (for example with foam) and more particularly the compressor, via silent blocks for example.

Preferably, the adsorbent used in the PSA system is an absorbent, preferably of the zeolite X or LSX type, exchanged by more than 80% with lithium, of the type of those described in EP-A-785020.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Oxygen concentrator portable by a patient permitting producing a gas flow containing from 50% to 95% of oxygen from air, including:

- air compression means,
- means for separating gas by adsorption with pressure variation, and
- electrical energy accumulating means having a charged life of at least 30 minutes,
- said concentrator having a total weight less than 10 kg, and
- the weight of the compression means (Mcomp), the weight of the gas separation means (Msieve) and the weight of the energy accumulating means (Mbattery) being such that:

$$0.5 < \frac{Mcomp}{Qp} < 3$$

$$0.15 < \frac{Mbattery}{Qp} < 2$$

$$0.05 < \frac{Msieve}{Qp} < 1$$

wherein Qp is the flow rate for the production of oxygen by the concentrator (in l/min) and the weights Mcomp, Mbattery and Msieve are expressed in kg.

2. Concentrator according to claim 1, wherein Qp is comprised between 0.5 and 4 l/min.

3. Concentrator according to claim 1, wherein Qp is between 0.5 and 2 l/min.

4. Concentrator according to any one of claims 1 to 3, wherein the ratio (Mcomp/Qp) is comprised between 0.5 and 2 kg/(l/min).

5. Concentrator according to any one of claims 1 to 4, wherein the ratio (Mbattery/Qp) is comprised between 0.15 and 1.2 kg/(l/min).

6. Concentrator according to any one of claims 1 to 5, wherein the ratio (Msieve/Qp) is comprised between 0.05 and 0.8 kg/(l/min).

7. Concentrator according to any one of claims 1 to 6, wherein Mcomp + Mbattery + Msieve is $\leq$ 8 kg.

8. Concentrator according to any one of claims 1 to 6, wherein Mcomp + Mbattery + Msieve $\leq$ 5 kg.

9. Concentrator according to any one of claims 1 to 8, wherein the gas separation means include several adsorbers each containing one or several adsorbents and operating according to PSA cycles.

10. Concentrator according to claim 9, wherein the duration of each production cycle is less than 30 seconds.

11. Concentrator according to any one of claims 1 to 10, wherein the adsorbent has a granulometry less than 1 mm and/or includes particles of zeolite X exchanged with at least one metallic cation selected from lithium, calcium, zinc, copper and their combinations.

12. Concentrator according to claim 11, wherein said zeolite X has a ratio Si/Al of about 1 to 1.25 and is exchanged by at least 80% with lithium cations.

13. Concentrator according to any one of claims 1 to 12, wherein the compression means are adapted or controlled to compress air to a pressure comprised between 1 and 5 bars.

14. Concentrator according to claim 13, wherein said pressure is between 2.5 and 3.5 bars.

15. Concentrator according to any one of claims 1 to 14, wherein it includes means for temperature regulation permitting adjusting the temperature of the air supply and/or of the adsorbers to a value comprised between 10 and 60°C.

16. Oxygen concentrator portable by a patient permitting producing a gas flow containing 50% to 95% of oxygen from air, including:

- air compression means to compress the air to a pressure comprised between 1 and 5 bars,
- means for separating gas by adsorption with pressure variation, including several adsorbers each containing one or several adsorbents and operating according to PSA cycles, the duration at each production cycle being less than 30 seconds and a: least one adsorbent being a zeolite exchanged with at least one metallic cation selected from lithium, calcium, zinc, copper and their combinations,
- electrical energy accumulating means having a charge life of at least 30 minutes,
- said concentrator having a total weight less than 10 kg, and
- the weight of the compression means (Mcomp), the weight of the gas separation means (Msieve) and the weight of the energy accumulating means (Mbattery) being such that:

$$0.5 < \frac{Mcomp}{Qp} < 3$$

$$0.15 < \frac{Mbattery}{Qp} < 2$$

$$0.05 < \frac{Msieve}{Qp} < 1$$

wherein Qp is the flow rate of oxygen produced by the concentrator in l/min) and the weights Mcomp, Mbattery and Msieve are expressed in kg,

- said air compression means, said means for separating gas by adsorption and said electrical energy accumulating means being disposed within at least one housing,
- said housing moreover including means for controlling or adjusting the operation of the concentrator and at least one system of securing or carrying the concentrator.

17. Concentrator according to claim 16, wherein the means for controlling or adjusting the operation of the concentrator include at least one start/stop means to start or stop the operation of the concentrator.

18. Concentrator according to claim 17, wherein the start/stop means includes an actuating button or a control member actuable by the operator.

19. Concentrator according to any one of claims 16 to 18, wherein the securement or carrying means of the concentrator include at least one carrying handle and/or at least one shoulder strap or a band and/or at least one means for suspending from the belt.

20. Concentrator according to claim 1 or 16, wherein it includes means for adjusting the flow rate of gas to be produced by the means for separating gas by adsorption.

21. Oxygen concentrator portable by a patient, substantially as herein described with reference to the accompanying drawings.

DATED: 31 July 2003

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Patent Attorneys for:
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ET L'EXPLOITATION DES GEORGES CLAUDE and
AIR LIQUIDE SANTE (INTERNATIONAL)

David B Fitzpatrick

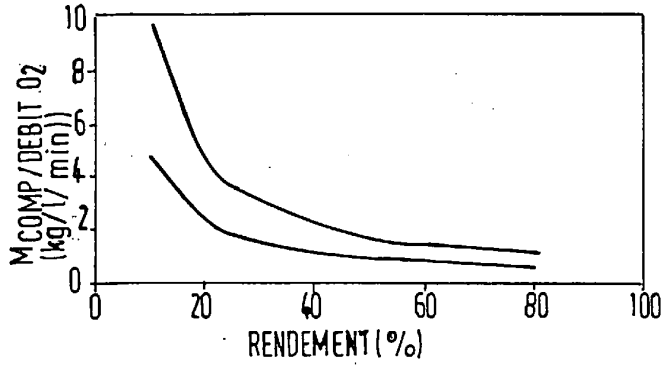
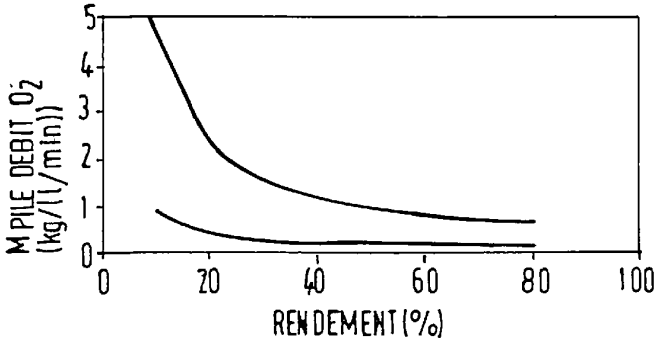

10
8
6
4
2
0
0
20
40
60
80
100
MCOMP/DEBIT O2
(kg/(l/min))
RENDEMENT (%)

FIG.1


5
4
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1
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0
20
40
60
80
100
MPILE DEBIT O2
(kg/(l/min))
RENDEMENT (%)

FIG.2

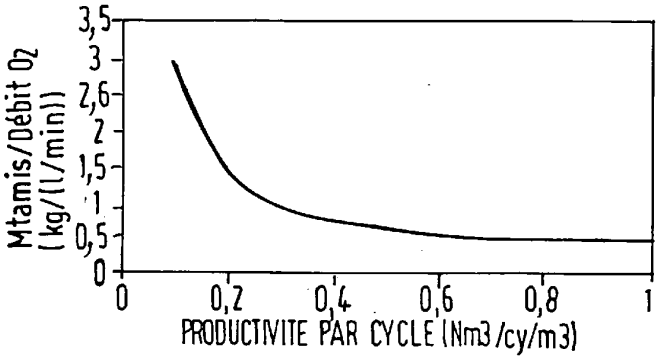
Mtamis/Débit O2
(kg/(l/min))
3,5
3
2,6
2
1,5
1
0,5
0
0
0,2
0,4
0,6
0,8
1
PRODUCTIVITE PAR CYCLE (Nm3/cy/m3)

FIG.3

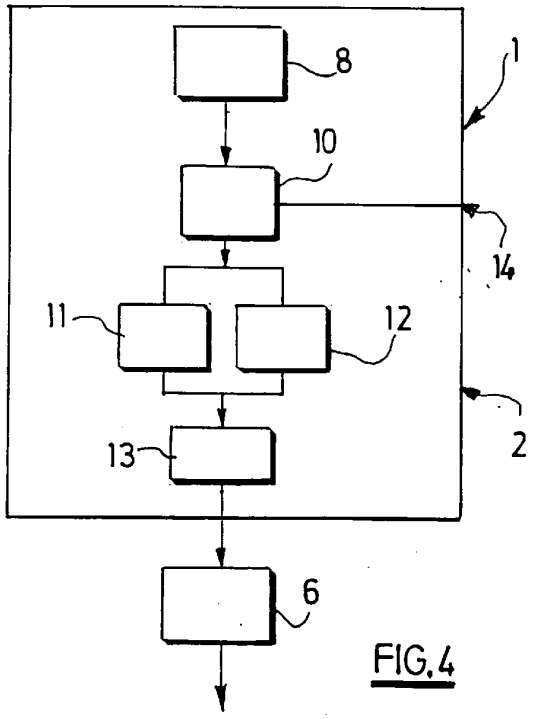
8
1
10
14
11
12
2
13
6

FIG.4

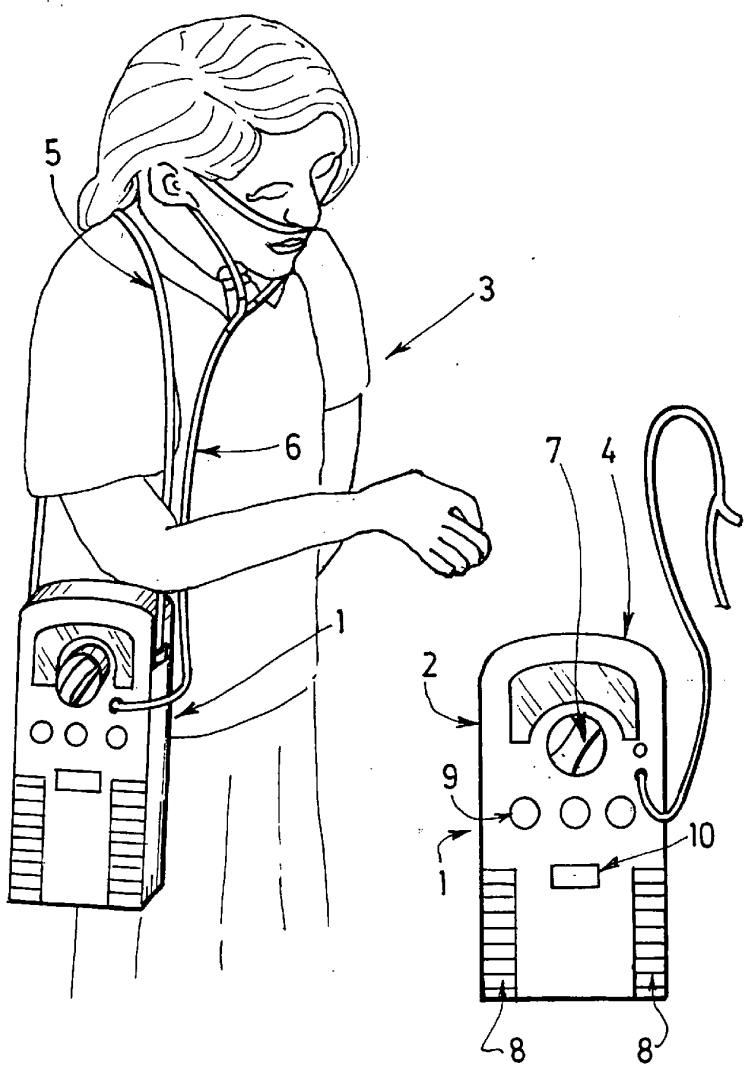

FIG.5