Aug. 11, 1925. 1,549,061

A. J. J. CHENU

PROCESS AND APPARATUS FOR THE RENEWAL OF THE GAS OF AEROSTATS AND THE LIKE

Filed Aug. 31, 1923 3 Sheets-Sheet 1

Fig.1

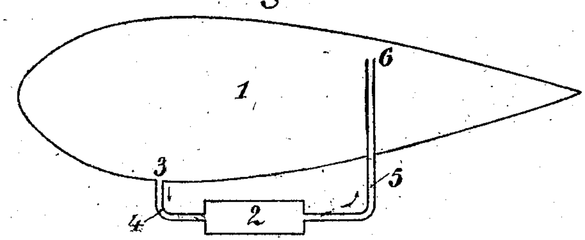


Fig.2

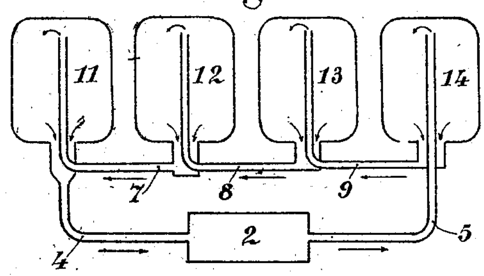


Fig.3

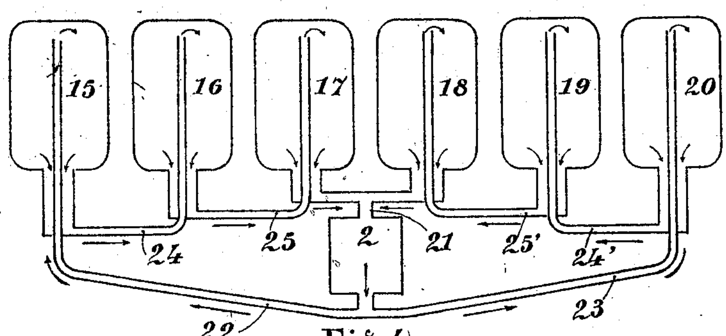
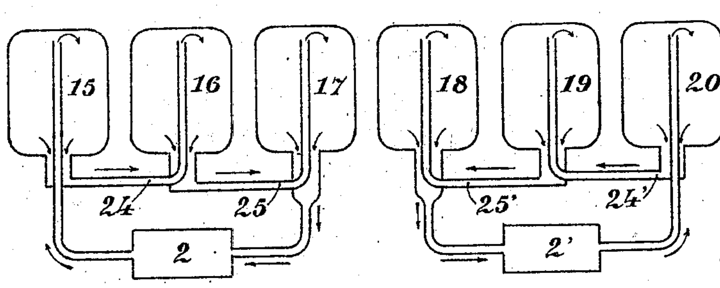


Fig.4



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his Attorney

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PROCESS AND APPARATUS FOR THE RENEWAL OF THE GAS OF AEROSTATS AND THE LIKE

Filed Aug. 31, 1923 3 Sheets-Sheet 2

Fig. 5

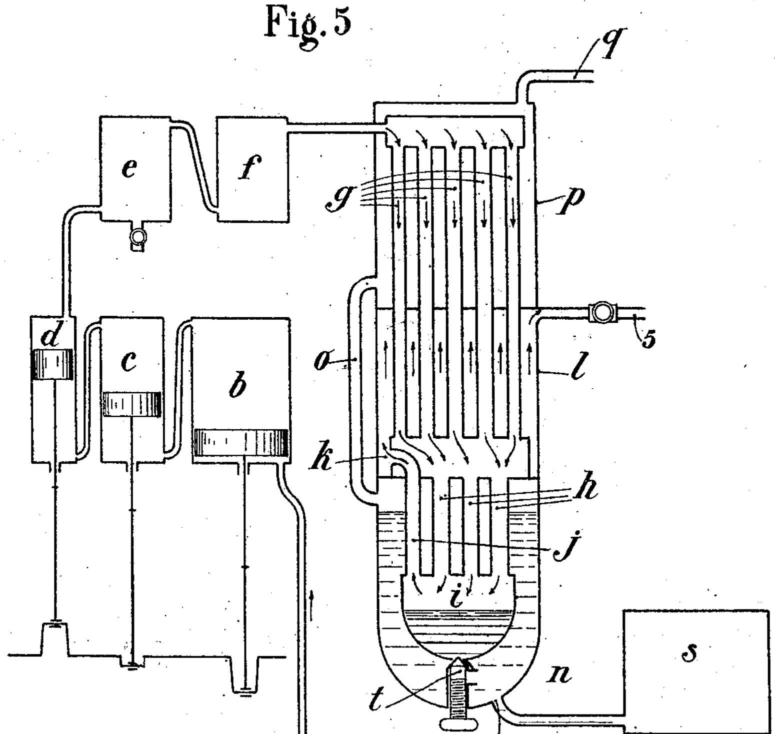
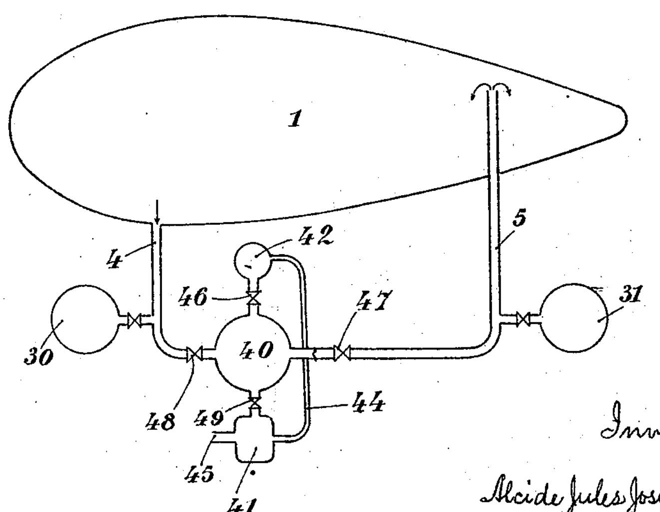


Fig. 9



Inventor

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by Ottomunrs

his Attorney

Fig. 6

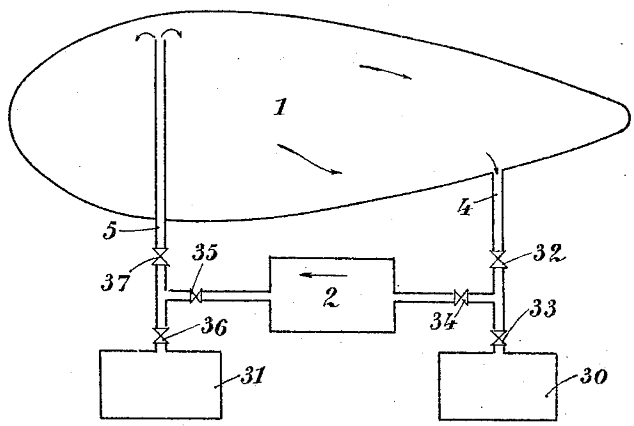


Fig. 7

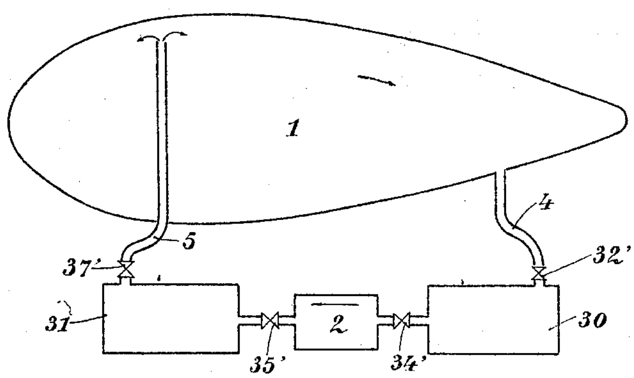
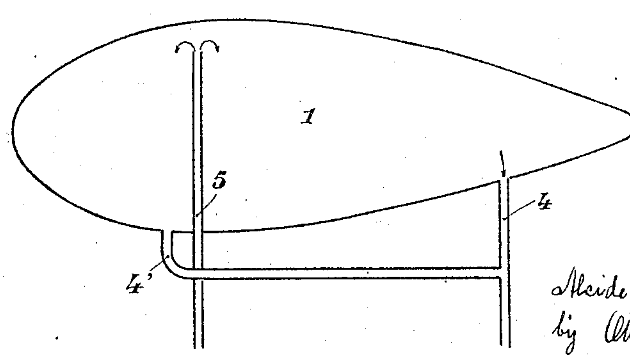


Fig. 8



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Patented Aug. 11, 1925. **1,549,061**

UNITED STATES PATENT OFFICE.

ALCIDE JULES JOSEPH CHENU, OF BILLANCOURT, FRANCE.

PROCESS AND APPARATUS FOR THE RENEWAL OF THE GAS OF AEROSTATS AND THE LIKE.

Application filed August 31, 1923. Serial No. 660,286.

To all whom it may concern:

Be it known that I, Alcide Jules Joseph Chenu, citizen of the French Republic, residing at Billancourt, Seine, in the French Republic, have invented new and useful Improvements in Processes and Apparatus for the Renewal of the Gas of Aerostats and the like, of which the following is a specification.

The present invention has for its object a process for the regeneration or renewal of the gas contained in aerostats or in any closed capacities containing a light gas (hydrogen, helium or the like) when said gas has lost part of its lifting power by reason of air having passed through the envelope.

This process has the advantage that it can be put in use without deflating the envelope or emptying the capacity, and consequently, in case of an aircraft in obviating all preparatory operations and the operations consecutive to deflation and inflation, as well as the eventual damage to the envelope which may result from said operations. Moreover, the aircraft is immobilized for much less time than with known processes and the losses of light gas are reduced to the minimum.

According to the invention, the gas contained in the capacity is caused to pass through a purifier and then to return to the said capacity, the said gas following thus a closed circuit. The gas is preferably taken from the lower part of the capacity and returned to the upper part thereof.

Other characteristic features of the invention will appear from the following description, reference being had to the accompanying drawings given by way of example and in which:

Figs. 1 to 4 and 6 to 9 show in a diagrammatic manner various installations for carrying out the improved process,

Fig. 5 shows in a diagrammatic manner a purifier intended to the liquefaction of the foreign gases to be withdrawn from the gas to be purified.

Fig. 1 represents in a diagrammatic manner the circulation of the gas in the case of an aircraft with a single receptacle. 1 is the receptacle of the aircraft, 2 is a purifier of any type. According to the invention, the impure gas is taken from the aircraft at 3 at the lower part of the receptacle 1; it flows through the conduit 4, traverses the purifier 2 and returns through the conduit 5 to the upper part of the inner receptacle of the aircraft at 6.

Fig. 2 shows in a diagrammatic manner a method of circulation of the gas in the case of an aircraft having four gas bags 11, 12, 13, 14. The impure gas which is drawn off from the lower part of the gas bag 11, flows through the conduit 4, traverses the purifying apparatus 2 and is delivered after having been purified to the upper part of the gas bag 14 through the conduit 5. The upper part of the gas bags 11, 12, 13 are connected with the lower parts of the gas bags 12, 13, 14 respectively by means of the conduits 7, 8, 9 as shown, in order to ensure the continuous circulation of the gas. It is evident that the purifier can be inserted in the closed circuit, not obligatorily in the position indicated above, but between two consecutive gas bags whatever, the last gas bag being then directly connected with the first.

Fig. 3 is a diagram showing a method of double symmetrical circulation in the case of an aircraft with six gas bags 15, 16, 17, 18, 19, 20. The impure gas is withdrawn at the same time from the two central gas bags 17 and 18 at their lower parts through the conduit 21 and the gas is forced back through the conduits 22 and 23 into the two end gas bags 15 and 20 at the same time at their upper parts. The upper parts of the gas bags 16, 17, 18 and 19 are connected with the lower parts of the gas bags 15, 16, 19 and 20 respectively by means of the conduits 24, 25, 25′, 24′. This disposition has the advantage to preserve the longitudinal equilibrium of the balloon.

Fig. 4 represents in a diagrammatic manner a disposition analogous to the preceding, except that use is made of two purifiers 2 and 2′ instead of a single one, so as to render independent the circuits of the gas of the gas bags 15, 16, 17 on the one hand, and 18, 19, 20 on the other hand.

The installation may be completed by a generator of light gas (hydrogen or the like) or by a feeding gas reservoir intended to furnish the amount of gas necessary to replace the volume of foreign gas eliminated from the receptacle. This amount may even consist of light gas contaminated with impurities, since it can be cleaned by passing through the purifier: for example, use can be made of the mixtures of hydrogen and nitrogen obtained from Dowson gas, after elimination of carbon monoxide

It is evident that in spite of the impure and heavier gas being taken from the lower parts, and of the purified and lightener gas being returned to the upper parts, mixing of the purified gas with the impure gas cannot be avoided. This drawback, in spite of appearances, has but a small importance. In fact, in the most unfavourable case, that of an aircraft with single receptacle, and even admitting that the purified gas becomes instantaneously diffused in the whole receptacle of the aircraft, calculation will show that after circulating through the purifier a volume of gas corresponding to this total capacity, one will have eliminated a proportion of impurities equal to

$$63\% \left(1-\frac{1}{e}=0.63\right),$$

e being the base of the hyperbolic logarithms) of what would have been eliminated if all mixing of the purified gas with the impure gas could have been avoided. After a second circulation, this rate will rise to

$$86.3\% \left(1-\frac{1}{e^2}=0.863\right).$$

Should the aircraft have several gas bags, the diffusion from one gas bag to another being prevented by the rapid circulation of the gas in the connecting conduits the extension of the preceding calculation shows that the proportion of impurities eliminated after a complete circuit of the total volume, will come nearer the higher possible rate of elimination, according as the number of gas bags is greater. With five gas bags, one eliminates after a complete circuit of the total volume, 88% of what would have been eliminated in case of no mixing of the purified gas with the gas to be purified.

This rate is near 99% if the circulation is carried on until the volume which has traversed the purifier represents 1½ times the total capacity of the gas bags.

Two auxiliary reservoirs may be added to the purifying circuits, said reservoirs containing either pure or impure gas. A more or less important volume of auxiliary gas being thus provided, it is possible to effect at different moments the purifying treatment properly so-called (passage of the impure gas through the purifier) and the renewal properly so-called (flow of pure gas into the balloon or other receptacle). This method has the advantage that it permits of no longer simultaneously circulating in the balloon and in the purifying devices; it is thus possible to considerably reduce the duration of immobilization of an aircraft when it is desired to renew the light gas thereof.

Fig. 6 shows an installation for carrying out this method; said installation comprises two reservoirs or groups of reservoirs 30, 31 disposed on either side of the purifying devices 2 and which may be reservoirs under variable pressure (compressed gas tubes) or reservoirs with variable volumes (gas holders). Valves or cocks shown in a diagrammatic manner permit of controlling the various necessary movements of the gas.

The device of Fig. 7 differs from the one represented in Fig. 6 simply in that the reservoirs or sets of reservoirs 30 and 31 are disposed in series in the circuit of the gases, instead of being disposed in shunt in this circuit, as shown in Fig. 6.

In each of the devices described, it will be necessary to insert blowers, compressors or expanders intended either to produce the movement of the gases or to moderate the same, or again to bring the gases to suitable pressures for their admission to or storage in the reservoirs 30 and 31. These blowers, compressors and expanders will be of any of the known types, their nature and their position depending upon the type and the disposition of the reservoirs and conduits employed. It may however be observed that in case in which the impure gas proceeding from the balloon is stored up in the reservoir 30 at a pressure sufficiently high by means of a compressor disposed on the conduit 4, it will be possible to partly or wholly suppress the compressors.

The installation shown in Fig. 6 can be set in operation according to two different methods:

First method: at the beginning of the operation, the reservoir 31 contains a mass m of pure light gas forming a reserve supply prepared in advance. The reservoir 30 is empty, or at least adapted to receive a volume of gas substantially equal to the reserve supply m (taking account of the different pressures if necessary). All the valves are closed.

The valves 32, 34, 35, 37 are opened and the purifying devices 2 are set working. The valves 33 and 36 are then opened in order to cause the gas contained in the reservoir 31 to flow to the reservoir 30 through the receptacle 1. When the regeneration of the gas of the balloon is sufficiently carried out, the valves 32 and 37 are closed and the balloon is again ready for use. A certain amount of impure light gas remains in the reservoir 30, said amount being at most equal to the amount of the original reserve supply m of the reservoir 31, if the latter has been entirely used. Hence the purifiers 2 still continue to be operated in order that the contents of the reservoir 30 returns to its starting reservoir 31 after being purified. The original reserve supply m is thus restored in its original situation, except for the losses occurring during the treatments.

Second method: to be used if the reserve supply m in the reservoir 31 is sufficiently important: At first, the valves 34, 35 are closed and all the other valves are opened, the purifier being hence stopped; under these conditions, the gas is caused to flow from reservoir 31 to reservoir 30 through the balloon or the capacity. This operation once completed, the valves 32 and 37 are closed and the balloon is again ready for use; the valves 34 and 35 are opened and the purifier is set working in order to return the impure gas from reservoir 30 to reservoir 31 through the purifier.

The circuit of the gas is still a closed circuit but as regards the time, the purifying properly so-called of the gas is delayed with respect to the renewal of the gas of the balloon.

The operation of the device of Fig. 7 is analogous to that of the device of Fig. 6, and two operating methods can be employed by opening the valves 34′ and 35′ at the same time as the valves 32′ and 37′ or not, the purifier being supposed to be set working at the moment when the valves 34′ and 35′ are opened.

According to Fig. 8, the withdrawal of the impure gas from the balloon 1 is effected no longer through a single conduit 4, but through two conduits 4 and 4′ connected together. The number of conduits 4, 4′ . . . as well as the number of conduits such as 5 may be as desired.

The impurities of the light gas may be eliminated by physical means or by chemical means. These impurities may be preferably liquefied (air in particular) by cooling the gas to be purified to the temperature of liquid air or nitrogen. The impure gas is preliminarily strongly compressed and freed under pressure from the traces of non-condensed water vapour and of carbonic acid, by means of suitable absorbents (soda, lime etc.).

A great consumption of liquid air or liquid nitrogen is avoided by providing a heat-exchanger in which are circulated on the one hand the cold purified gas, and on the other hand the impure gas to be cooled. The pressure at which the gas to be purified should be compressed, is higher according as the purity which it is desired to obtain, is itself greater.

Fig. 5 shows an installation for carrying out the above purifying process.

The impure gas is delivered to the purifier through the conduit 4. At b, c, d are shown the three cylinders of a compressor in which the gas is brought to a suitable pressure. This compressor may have any number of stages, and may be provided with the usual means for outer cooling and inner cooling by injection of water. At e is represented the water separator, and at f a drying vessel containing substances adapted to absorb water and carbonic acid, for instance soda or lime.

The impure gas, after having been compressed, dried and freed from carbonic acid, flows from the receptacle f, to a set of tubes g which is extended by another set of tubes h which in turn communicates with a receptacle i. The non-condensed part of this gas escapes through the tube k which opens into a chamber l surrounding the lower part of the set of tubes g, and escapes through the conduit 5, whence it is directed to the upper part of the balloon, as already set forth; an additional heat exchanger may be provided on the conduit 5.

The receptacle i and the tubes h are surrounded by a chamber n containing liquid air which is supplied by a liquid air machine s and brought by a tube r. The air produced by the evaporation of this liquid air is evacuated through a tube o which delivers it into a chamber p surrounding the upper part of the tubes g. The air finally escapes at q.

It will be understood that the gas to be purified which flows under pressure from the vessel f is cooled successively at the upper part of the tube g by the cold gas contained in the chamber p and produced by the evaporation of the liquid air or nitrogen and then in the lower part of the tubes g by the purified light gas has reached the chamber l through the tube k after having passed through the tubes h; the cooling is completed in these tubes h.

The impurities of the gas to be purified, which are condensed in the receptacle i, are evacuated at t either into the liquid air which surrounds the receptacle i when these impurities are solely constituted by the elements of the air, or to the outside if they may contain combustible substances.

In order to increase the purity of the light gas issuing from the purifier, or to reduce the compression which must be given to this gas in order to obtain a determined degree of purity, a depression may be maintained above the liquid air or nitrogen used for the cooling of the compressed gas. If desired, this depression may be produced by the compressor which serves for the production of the liquid air, said compressor being caused to exhaust from the purifier the evaporated air or nitrogen when a sufficient amount of liquid air or nitrogen is obtained; a closed circuit is thus also provided for these gases, whereby the drying of the air to be liquefied is avoided. Lastly, the expansion of the compressed and purified light gas may be utilized in an engine for the recovery of a part of the power employed, or for cooling purposes.

The aggregate of the devices constituting the purifying apparatus (compressors, water and carbonic acid absorbers, heat exchangers, refrigerant with liquid air or nitrogen, liquid air or nitrogen machine and its accessories, recuperator of power from the compressed gas) can be united so as to form a purification group adapted to be transported upon a motor vehicle. In this case, the necessary power for the various operations will be supplied by the engines of the vehicle or vehicles.

Obviously, other processes may be employed for the absorption of the impurities, such for example as the absorption of the oxygen and nitrogen by carbide of calcium at red heat, calcium, magnesium, etc.

The impure gas may also be caused to diffuse through porous walls (through which the hydrogen and helium will pass more quickly than any other gas). In case the light gas of the aircraft is hydrogen, use can be made of a process based upon the known reactions of hydrogen upon oxide of iron, and of water vapour upon reduced iron; according to this process, the hydrogen contained in the mixture of hydrogen and air will be converted into water under the action of oxide of iron at a red heat, pure hydrogen being then produced by the action of the re-vaporized water upon reduced iron. The oxygen contained in the mixture is combined with the hydrogen at the beginning of the first reaction; the nitrogen and the other gases are eliminated in the gaseous state at the time of the condensation of the water vapour, between the first and the second reaction.

In practice, it is known that the production of hydrogen by the action of water vapour upon reduced iron, requires a considerable excess of water vapour (from two to six times the theoretical amount). It is thus necessary to vaporise a quantity of water much above what can be given by the reaction of the hydrogen on the oxide of iron in the first part of the operation, and thus to employ an auxiliary generator. Due to the difficulty of condensing the vapour mixed with nitrogen produced in the first reaction, it may be preferable to simply discharge the non-condensed mixture to the outside, and take from an outside source all the water intended to supply the vapour necessary for the production of hydrogen.

The method may be carried out with the installation shown in Fig. 9. In this figure, 40 is an apparatus (furnace or set of retorts) containing the oxide of iron which is subjected to alternative reductions and oxidations, 41 a water vapour condenser and 42 a vapour generator, the water feed of which can be partly obtained by the water condensed in the condenser 41 and supplied through the tube 44. The non-condensed gases are discharged from the condenser 41 through the conduit 45. The various movements of the gases are obtained by means of suitable valves as shown.

The operation of the installation is as follows: The valves 46 and 47 being closed, the impure gas flows from the capacity 1 through the conduit 4 and the valve 48 and enters the oxide of iron apparatus 40 in which it is converted into water vapour, nitrogen and carbonic acid. This mixture is sent through the valve 49 into the condenser 41 in which the water vapour is condensed, whilst the nitrogen and carbonic acid are discharged through the conduit 45.

During this first stage of the operation, the impure gas taken from 1 is replaced by equal volumes of pure hydrogen supplied from the reservoir 31. When the oxide of iron in the apparatus 40 is sufficiently reduced, the valves 48 and 49 are closed and the valves 46 and 47 are opened; the water vapour supplied by the generator 42 passing over the reduced iron in 40 produces hydrogen which is sent to the reservoir 31, or into the capacity 1, through the valve 47. When the iron is sufficiently re-oxidised, the valves 46 and 47 are closed again, the valves 48 and 49 are opened and another stage of reduction of oxide analogous to the first one takes place.

A condenser intended to separate the great excess of vapour which issues from the apparatus 40, from the hydrogen, may be inserted between the said apparatus 40 and the valve 47 as well as a drain cock adapted to send to the outside (or to the reservoir 30) the first portions of gas issuing from 40 at the beginning of the period of oxidation of the iron, said first portion being still contaminated with nitrogen.

Lastly, the purifying device which has just been described may be made double so as to afford a continuous working, one of the devices being in the stage of reduction whilst the other is in the stage of oxidation. In this case, the reservoirs 30 and 31 may be suppressed since one of the purifiers will always supply pure gas to the capacity 1 whilst the other purifier will receive the impure gas. It will suffice to have an auxiliary source of hydrogen intended to compensate for the losses, as already mentioned.

Having now described my invention, I declare that what I claim as new and desire to secure by Letters Patent is:

1. A process for the renewal of the light gas of an aerostat, which consists in causing the gas to follow a closed circuit without deflating the envelope, the impure gas being preferably taken from the lower part of the aerostat, passing then through suitable purifying means and returning into the

aerostat preferably at the upper part thereof.

2. A process for the renewal of the light gas of an aerostat with a plurality of gas bags, which consists in causing the gas to follow a closed circuit without deflating the gas bags, the impure gas being taken from one of the gas bags preferably at the lower part thereof, passing then in suitable purifying means and returning in another gas bag preferably at the upper part thereof, the gas circulating in the intermediate gas bags in such a manner that it escapes at the lower part of each gas bag and enters at the upper part of the next one.

3. A process for the renewal of the light gas of an aerostat, which consists in causing the gas to follow a closed circuit without deflating the envelope, the impure gas being preferably taken from the lower part of the aerostat, passing then through suitable purifying means and returning into the aerostat preferably at the upper part thereof and supplying to the aerostat an amount of pure gas equal to the losses of the purification.

4. A process for the renewal of the light gas of an aerostat with a plurality of gas bags, which consists in causing the gas to follow a closed circuit without deflating the gas bags, the impure gas being taken from one of the gas bags preferably at the lower part thereof, passing then in suitable purifying means and returning in another gas bag preferably at the upper part thereof, the gas circulating in the intermediate gas bags in such a manner that it escapes at the lower part of each gas bag and enters at the upper part of the next one and supplying to the aerostat an amount of pure gas equal to the losses of the purification.

5. A process for the renewal of the light gas of an aerostat which consists in causing the gas to follow a closed circuit without deflating the envelope, the impure gas being preferably taken from the lower part of the aerostat, passing then through suitable purifying means and returning into the aerostat preferably at the upper part thereof and supplying to the aerostat an amount of pure gas contained in an auxiliary reservoir disposed after the purifying means, an equal amount of impure gas being received in a second reservoir disposed before the purifying means.

6. A process for the renewal of the light gas of an aerostat with a plurality of gas bags, which consists in causing the gas to follow a closed circuit without deflating the gas bags, the impure gas being taken from one of the gas bags preferably at the lower part thereof, passing then in suitable purifying means and returning in another gas bag preferably at the upper part thereof, the gas circulating in the intermediate gas bags in such a manner that it escapes at the lower part of each gas bag and enters at the upper part of the next one, and supplying to the aerostat an amount of pure gas contained in an auxiliary reservoir disposed after the purifying means, an equal amount of impure gas being received in a second reservoir disposed before the purifying means.

7. A process for the renewal of the light gas of an aerostat which consists in causing the gas to follow a closed circuit without deflating the envelope, the impure gas being preferably taken from the lower part of the aerostat, passing then in purifying means wherein the gas is compressed and cooled by means of liquid air for eliminating the impurities in a liquid state, the pure gas issued from the purifying means returning into the aerostat preferably at the upper part thereof.

8. A process for the renewal of the light gas of an aerostat with a plurality of gas bags which consists in causing the gas to follow a closed circuit without deflating the gas bags, the impure gas being taken from one of the gas bags preferably at the lower part thereof, passing then through purifying means wherein the gas is compressed and cooled by means of liquid air for eliminating the impurities in a liquid state, the pure gas issued from the purifying means returning in another gas bag preferably at the upper part thereof, the gas circulating in the intermediate gas bags in such a manner that it escapes at the lower part of each gas bag and enters at the upper part of the next one.

In testimony whereof I have signed my name to this specification.

ALCIDE JULES JOSEPH CHENU.