Aug. 5, 1941. M. L. TAYLOR 2,251,430

INFLATION SYSTEM AND APPARATUS FOR OPERATING THE SAME

Filed Jan. 19, 1940 3 Sheets-Sheet 1

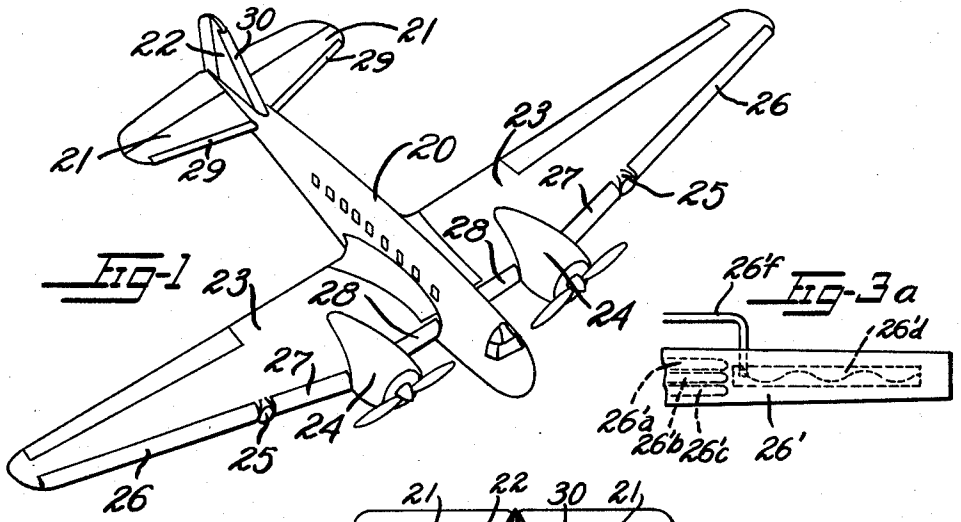


Fig-1

Fig-3a

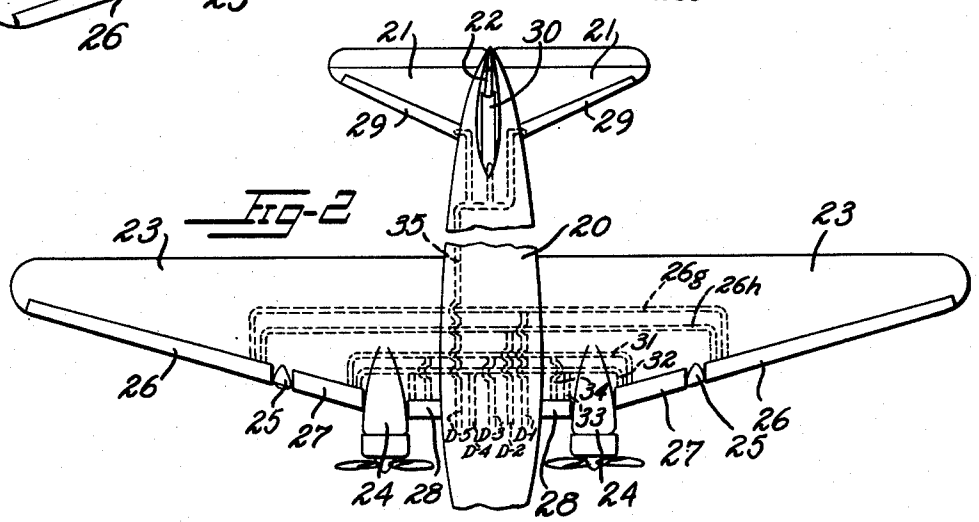


Fig-2

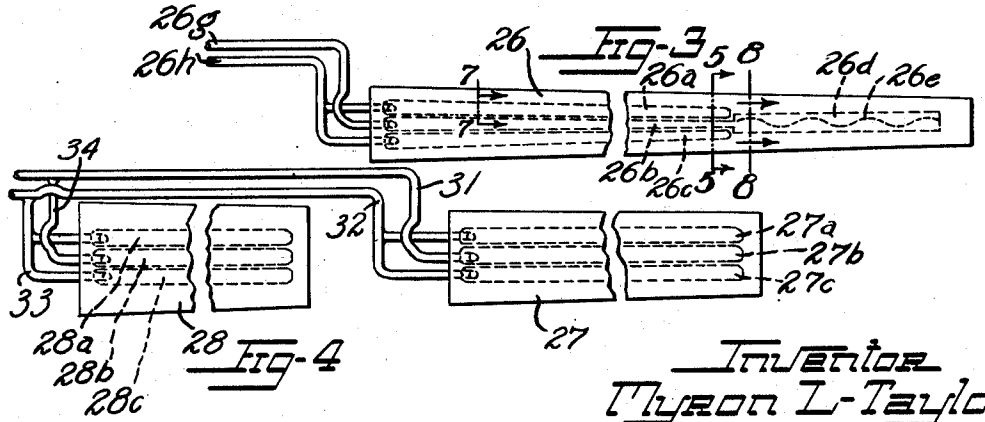


Fig-4

Fig-3

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INFLATION SYSTEM AND APPARATUS FOR OPERATING THE SAME

Filed Jan. 19, 1940 3 Sheets-Sheet 2

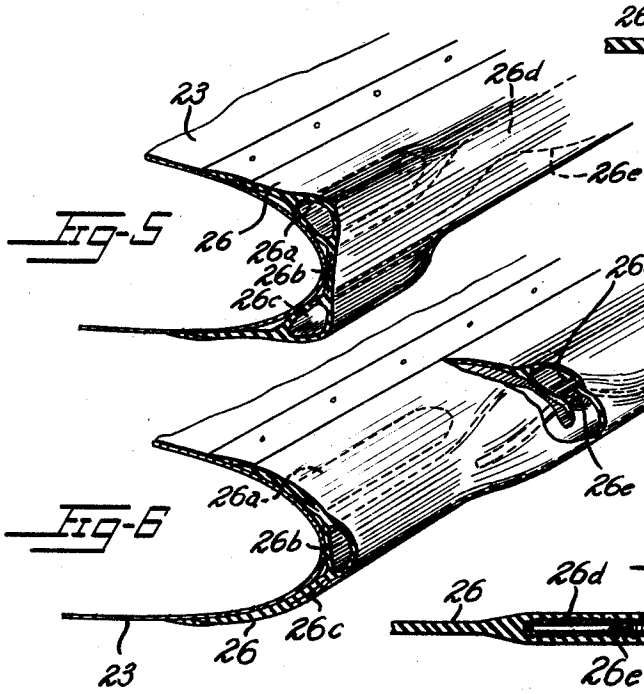


Fig-5

Fig-6

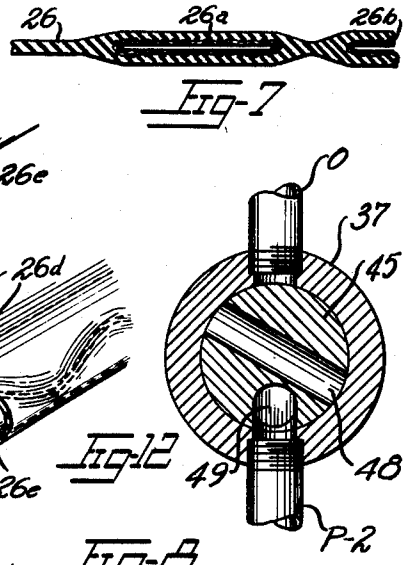


Fig-7

Fig-8

Fig-12

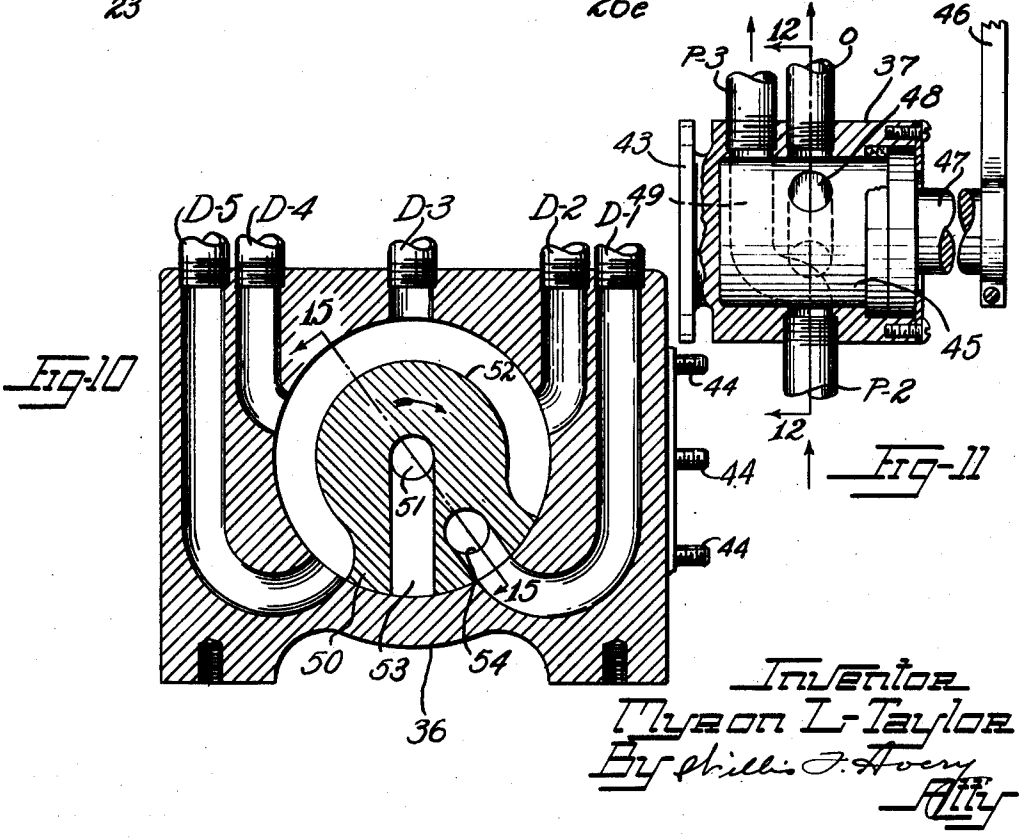


Fig-10

Fig-11

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INFLATION SYSTEM AND APPARATUS FOR OPERATING THE SAME

Filed Jan. 19, 1940 3 Sheets-Sheet 3

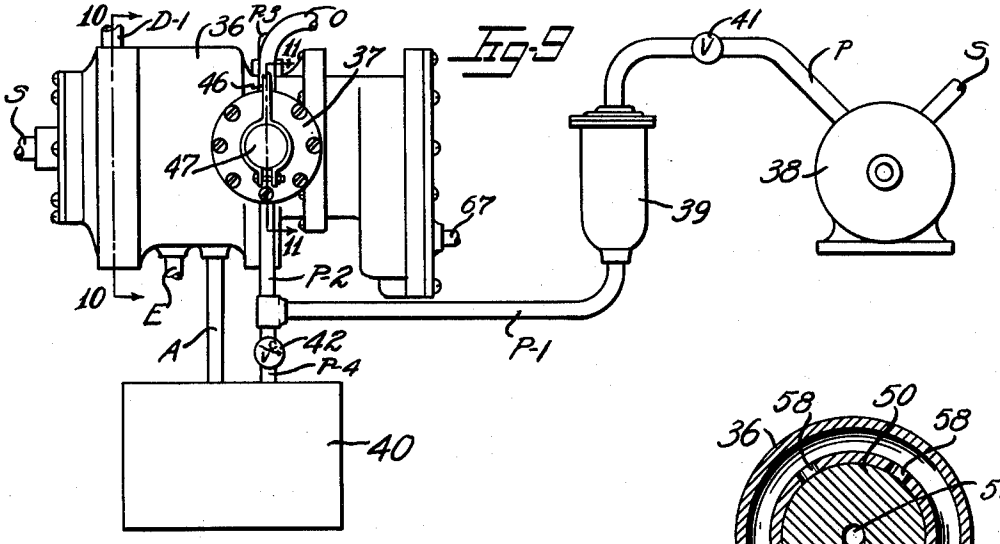


Fig-9

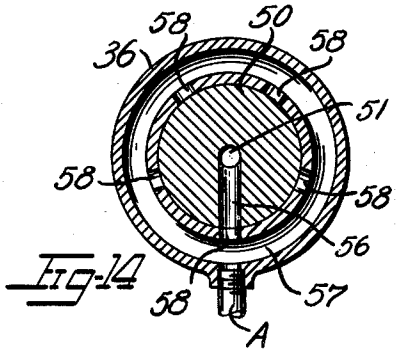


Fig-14

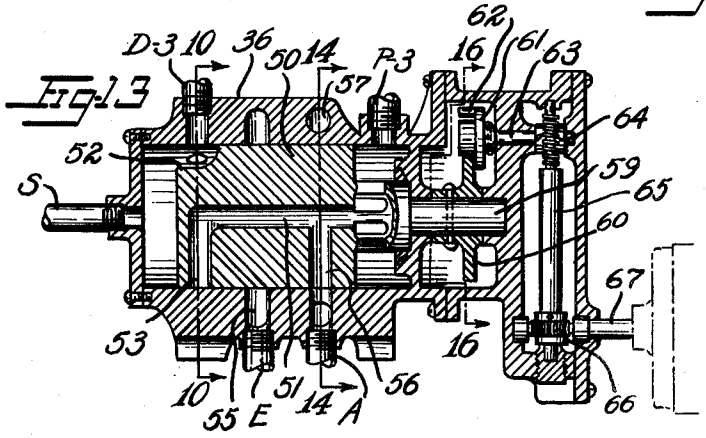


Fig-13

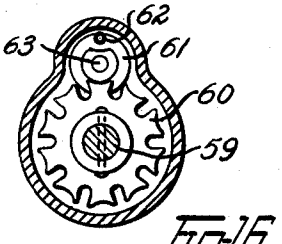


Fig-16

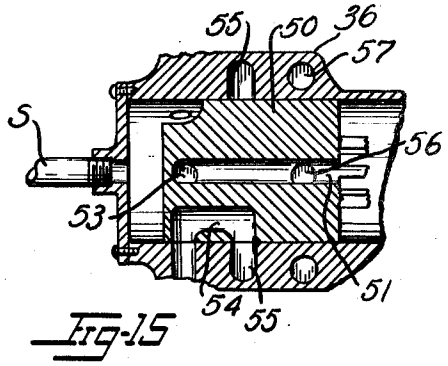


Fig-15

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Patented Aug. 5, 1941 2,251,430

UNITED STATES PATENT OFFICE

2,251,430

INFLATION SYSTEM AND APPARATUS FOR OPERATING THE SAME

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Application January 19, 1940, Serial No. 314,619

9 Claims. (Cl. 244—134)

This invention relates to systems of inflation elements applicable for ice elimination on wings and other airfoils and surfaces of aircraft, and to apparatus for operating and controlling the same.

Protective units comprising extensible surfaces extended intermittently by internal inflatable tubes, operating for example in the manner disclosed in Geer Patent No. 1,998,809, have been found efficacious heretofore in the elimination of ice accumulations on aircraft. In the operation of such units heretofore a unit on a starboard wing has been inflated in alternation with a corresponding unit on a port wing, which in some cases has had a disturbing effect owing to the fact that the aerodynamic characteristics of the wings have been changed in alternation as a result of the alternate inflations. In the case of large installations it is sometimes not desirable to inflate large units on both wings simultaneously because the lift-drag ratio may be objectionably decreased, even though only temporarily, and also because the simultaneous inflation of a plurality of large units imposes excessive demands upon the pump or other air pressure supply. According to one phase of the invention objects are to minimize reduction in the lift-drag ratio of the wings or other part upon which the inflatable elements are operated, and to provide for symmetrical or corresponding operation of the inflatable elements with respect to the port and starboard wings or other airfoils so that aerodynamic changes are the same for both sides of the aircraft.

In the operation of inflatable units heretofore it has been the practice to control the inflation by a two-phase cycle; that is, there has been the inflating phase, which has been followed by the deflating phase. In the deflating phase the air under pressure in the unit has been simply exhausted overboard, or in some cases the air under pressure has been withdrawn from the unit by connection to the suction side of a pump instead of the atmosphere. Where the air has been exhausted overboard difficulty has sometimes been encountered as a result of failure of the unit to deflate completely and remain thus deflated until the next pressure phase. Fluttering has sometimes occurred. In the cases where the air has been withdrawn by suction, an undesirable burden has been placed upon the suction pump in withdrawing the large volume of air under pressure where such pump has been used also to maintain suction for instruments and other uses, and loss in suction has occurred. It is an object of the invention to provide for obviating these difficulties by the provision of a three-phase cycle of operation so that the inflating phase is followed by an overboard exhausting phase to rid the unit of the bulk of its air, which in turn is followed by a suction phase to maintain the unit in its fully deflated condition until the time of the next inflating phase.

Heretofore inflation units have been operated by rotary valves, the ports of which have opened and closed gradually. It has been found that the extensible surfaces are most effective in their function of breaking up accumulated ice when the inflation is effected suddenly, and it is an object of the invention to provide for effecting quick inflation and quick deflation.

It is still a further object of the invention to provide a system including an accumulator for compressed air that will serve in an auxiliary capacity to augment the supply of air from the pump and to provide also for supplying the accumulator from the inflating pressure pump by intermittent connection between the inflation phases. This lessens the size requirements of the pump and also facilitates the attainment of the hereinbefore stated object of providing quick inflation.

Of the drawings,

Fig. 1 is a perspective view of an airplane having a system of inflatable units mounted thereon.

Fig. 2 is a plan view of the airplane of Fig. 1 with a system of piping for the inflatable units indicated diagrammatically by broken lines.

Fig. 3 is a developed elevation, with parts broken away, of the outboard inflatable unit of the port wing.

Fig. 3—A is a view like the right-hand portion of Fig. 3 showing a modified construction.

Fig. 4 is a developed elevation, with parts broken away, of the two inboard inflatable units of the port wing.

Fig. 5 is a view in perspective and cross-section of the outboard unit mounted upon the wing, the view being taken at the line 5—5 of Fig. 3, this view being of the unit in one of its two inflated conditions.

Fig. 6 is a view like Fig. 5, but showing the unit in the other of its two inflated conditions.

Fig. 7 is a section taken along the line 7—7 of Fig. 3.

Fig. 8 is a section taken along the line 8—8 of Fig. 3.

Fig. 9 is an elevation of distributor mechanism constructed according to and embodying the invention, with a pump, a separator, and an accumulator connected thereto.

Fig. 10 is a section taken along the line 10—10 of Fig. 9. For convenient reference, the section line 10—10 is also indicated on Fig. 13.

Fig. 11 is a section of control valve mechanism taken along the line 11—11 of Fig. 9.

Fig. 12 is a section taken along the line 12—12 of Fig. 11.

Fig. 13 is a vertical section of the distributor mechanism of Fig. 9, the position of the parts being so indicated on Fig. 10.

Fig. 14 is a section taken along the line 14—14 of Fig. 13.

Fig. 15 is a section taken along the line 15—15 of Fig. 10.

Fig. 16 is a section taken along the line 16—16 of Fig. 13.

With reference first to Figs. 1 to 8, the invention is illustrated as applied to an airplane of the monoplane type comprising a fuselage 20, having a tail group comprising horizontal stabilizers 21, 21 and a vertical stabilizer 22, and having wings 23, 23 each having a motor nacelle 24 and a landing light 25. A plurality of inflatable units, for preventing the accumulation of ice, is provided at the leading edge of the wings and stabilizers. These units include an outboard wing unit 26 extending from the wing tip to the landing light 25, an intermediate unit 27 between the landing light and the nacelle 24, an inboard wing unit 28 between the nacelle and the fuselage, a unit 29 on each horizontal stabilizer and a unit 30 on the vertical stabilizer. Each unit is constructed of elastic rubber-like material suitably reinforced and secured upon the wing or other airfoil and each unit comprises one or more inflatable tubes. In the illustrated embodiment the stabilizer units 29, 29 and 30 each comprise a single tube for inflation and each wing unit comprises three tubes for inflation.

The three inflatable tubes of the outboard member 26 are indicated at 26*a*, 26*b*, and 26*c*. These three tubes extend from the inboard end of this unit to a position near the wing tip where the wing section is considerably thinner, where an extension of the center tube 26*b* is provided as a double-compartment tube 26*d*, having a middle partition 26*e* in sinuous form to facilitate good curvature of this portion of the unit, as indicated in Fig. 6, for effective ice removal despite the thinness of the wing section in this region. The units 27 and 28 each have three tubes extending nearly the full length of the unit, these tubes being indicated at 27*a*, 27*b*, and 27*c*, and 28*a*, 28*b*, and 28*c*.

Each of the wing units is inflated by groups of the tubes in alternation. The outboard units 26 of the two wings are inflated by tubes 26*a*, and 26*c* together as indicated in Fig. 5, and 26*b*, and 26*d* together as indicated in Fig. 6. Tubes 27*a* and 27*c* of the intermediate unit 27 are inflated together and in alternation with the central tube 27*b*, and tubes 28*a* and 28*c* of the inboard unit 28 are operated together and in alternation with the central tube 28*b*. The three single tubes of the tail group may be inflated together.

To the end of minimizing aerodynamic disturbances to the aircraft upon inflation, provision is made for inflating only some of the units at a time so that only portions of the wings or other airfoils will be affected, and provision is made also for inflating units symmetrically on the two wings so as not to create lateral instability as a result of the inflation. Also, provision is made for inflating and deflating each group of tubes of each unit, which group may be regarded as an inflatable unit, in a three-phase cycle consisting of an inflating phase, and then a phase of exhausting the element to the atmosphere, which is followed in turn by a phase of suction to the element so as to hold it in its deflated condition until the next pressure phase. The suction phase has the advantage of resisting the effect of atmospheric suction at the outside of the unit tending to pull the outer surface of the element away from the wing and cause fluttering thereof in an undesirable manner.

In cases of very long wing span it is sometimes desirable to apportion the inflation of the outboard unit in two or more portions span-wise as indicated, for example, in the modified construction of Fig. 3*a*. Here an outboard unit 26'*d* is not inflated by connection to a central tube 26'*b*, but is inflated and deflated by a separate pipe connection 26'*f*. Thus in this embodiment three inflatable units are provided, the tubes 26'*a* and 26'*c* being operated as a unit, the tube 26'*b* being operated as a second unit, and the tube 26'*d* being operated as a third unit, preferably together with some other unit further inboard.

To these ends, in the illustrative embodiment of the invention, a piping system indicated diagrammatically in Figs. 2, 3 and 4, is provided. In this system, inflatable units or elements (each comprising one or more inflatable tubes) of a portion of each wing is operated in common with the corresponding inflatable unit which is symmetrically located on the other wing. The communicating pipes for the two units of the outboard members 26, 26, are indicated at 26*g*, 26*h*, the piping for the two units of the intermediate member 27 is indicated at 31, 32, the piping for the two units of the inboard member 28 is indicated at 33, 34 and the common piping for the three tubes of the tail group is indicated at 35. The five pipe lines referred to have independent connections D—1, D—2, D—3, D—4 and D—5 leading to air distributor mechanism. It will be understood that the inflatable units may be operated in any desired grouping, and while five groups are illustrated, this number may be varied as desired.

Referring now to Figs. 9 to 15, mechanism is provided for operating the five groups of inflatable units alternatively, in the form shown, in a five-division cycle, each unit being operated in three successive phases comprising a pressure phase, an exhaust phase and a suction phase. These operations are effected through a rotary distributor valve having, in the illustrated form, ten distributing positions in each rotation.

The distributor mechanism is indicated at 36. Attached at the side of this mechanism is a manually operated two-position valve 37 controlling the flow of air under pressure into the distributor from a pump 38 through an oil separator 39 by means of pipes P, P—1 and P—2, and also are under pressure from an accumulator 40 by means of a pipe P—4 leading into pipe P—2. The pipe P has a shut-off valve 41 and the pipe P—4 has a check valve 42 permitting air to enter the distributor mechanism from the accumulator 40 but not to flow in the reverse direction. The accumulator 40 is supplied with air under pressure intermittently through a connection A of the distributor mechanism. The distributor mechanism includes also a suction connection S leading to the suction side of the pump 38, an exhaust connection E to atmosphere. Five connections D—1 to D—5 connected to the five pipe

lines of the system supplying the inflatable units, and a pressure supply pipe P—3 connecting the distributor valve with the control valve 37.

The control valve 37 comprises a casing having a flange 43 to permit mounting of it at the side of the distributor mechanism by means of stud bolts 44, 44. The pressure supply connection P—2 enters the casing from the bottom and diametrically opposite this connection at the top of the casing is an overboard dump connection O. The remaining connection P—3 at the top of the casing supplies air under pressure to the distributor mechanism. Within the casing is a valve rotor 45 that is moved between two positions by a manually operated lever 46 secured to an extension 47 of the rotor. The rotor has a through aperture 48 located to by-pass air under pressure directly overboard in a position of the valve in which such aperture is aligned with connections P—2 and O. In the other position of this valve, shown in Figs. 11 and 12, which is the "on" position, an aperture 49 in the rotor puts pressure pipe P—2 in connection with pipe P—3 leading to the distributor mechanism.

The distributor mechanism comprises a casing in which is mounted a distributing rotor 50. The rotor 50 is centrally and axially cored from its right-hand end, as seen in Figs. 13 and 15 to a position short of its left-hand end, to provide a manifold 51 for air under pressure from the pipe connection P—3, the latter being located at the right-hand end of the rotor 50 and the rotor being cut away suitably to permit entrance of the air under pressure into the manifold 51 in all positions of the rotor.

The rotor 50 terminates short of the end of the casing at its left-hand end to provide communication with the suction line S. The five connections D—1 to D—5 are equally spaced about the circumference of the rotor at a plane within the left-hand end portion of the rotor where the outer periphery of the rotor is cut away to the extent indicated at 52 to permit four out of five of the connections D—1 to D—5 to be in communication with the suction line at any one time. The part of the rotor not cut away is formed with a passage 53 to pass air under pressure from the manifold 51 to each of the connections D—1 to D—5 in turn.

A passageway 54 is provided in the rotor at a position $\frac{1}{10}$ of a revolution behind the pressure passage 53, which passageway 54 places each of the connections D—1 to D—5 in turn into communication with an exhaust connection E to atmosphere following each inflation. For this purpose the passage 54, which connects intermittently with the connections D—1 to D—5, is in constant connection with an annular exhaust manifold 55 at a position of the rotor to the right of the connections D—1 to D—5.

Between the intervals of inflation, the air under pressure from the pump is supplied to the accumulator 40 through the connection A by means of a passage 56 in the rotor in communication with the manifold 51. At the intervals between inflations the air pressure is valved into the connection A through an annular manifold 57 having five apertures 58, 58 located as shown for example in Fig. 14, to deliver air under pressure intermittently to the accumulator.

In the position of the parts illustrated in the several views of the drawing no pressure is being supplied to any inflatable element, the pressure being supplied to the accumulator in this position, the air being exhausted from one inflatable unit, and the suction being applied to the remaining four units.

The next position of the rotor 50 is $\frac{1}{10}$ of a revolution clockwise as viewed in Fig. 10, in which position air under pressure will be supplied to an inflatable unit through the lower left-hand connection D—5, the exhaust connection and the accumulator connection will be closed, and suction will be applied to the four units through connections D—1 to D—4. Each connection D—1 to D—5 is subjected in succession to the three phases of pressure, exhaust and suction.

One complete revolution of the rotor 50 constitutes a cycle of operation for the system and during this time any one unit will have had inflation pressure applied for $\frac{1}{10}$ part of the revolution of rotor 50, exhaust to atmosphere for $\frac{1}{10}$ part of such revolution and suction for $\frac{8}{10}$ part of the revolution.

Because a constant rotation of the distributor rotor would cause the ports, especially the inflation ports, to open gradually, the inflation, if such were the case, would be correspondingly gradual. It has been found that more effective ice removal is accomplished if the inflation of the unit can be effected suddenly. To this end I provide quick-acting stop-motion drive means for the rotor 50 so that the ports will be opened and closed quickly and held for predetermined intervals in each of the ten operating positions of the rotor. The rotor 50 is driven by means of a shaft 59 at its right-hand end upon which is secured the slotted wheel 60 of a Geneva stop-motion drive. A drive wheel 61 comprising an engaging pin 62 is mounted upon a shaft 63 which is driven through gearing 64 from a vertical shaft 65 which in turn is driven through gearing 66 from a shaft 67 of a suitable motor.

The desired quick inflation of the units is assisted by the auxiliary air under pressure from the accumulator or reservoir 40 which is supplied in the intervals between inflations as hereinbefore described. During the intervals of inflation the air from the accumulator, when the pressure in the latter is sufficient, passes through the connection P—4, including check valve 42, to augment the supply of air from the pressure line P—1 into the line P—2.

It is believed the detailed operation of the apparatus will be clear from the foregoing description. With the pump 38 in operation and the valve 41 open and the valve 37 in the by-pass position, air from the pump is discharged overboard through the connection O. If the rotor 50 of the distributor be now turned by its motor, suction will be supplied to each inflatable element through its connection $\frac{1}{5}$ of the time. When it is desired to put the inflatable elements into intermittent cyclic operation, handle 46 of the control valve operation is moved to disconnect the by-pass 48 and to put the pressure line P—2 into connection with the distributor through the connection P—3. Then, as hereinbefore described, each inflatable unit will be connected successively, and by quick-action, stop-motion to inflation pressure, then exhaust to the atmosphere and then to suction, all in cylic operation and symmetrically with respect to the fuselage of the aircraft. By the successive and cyclic inflations ice is effectively removed without reducing the lift-drag ratio or otherwise affecting the aerodynamic characteristics of the aircraft to any objectionable extent.

Variations may be made without departing

from the scope of the invention as it is hereinafter claimed.

I claim:

1. A system of inflation units for aircraft comprising inflatable units arranged on port and starboard airfoils of the aircraft with a plurality of said units on each of said airfoils said inflatable units being disposed on each airfoil at positions along the airfoil span-wise thereof, and means for inflating units on one of said airfoils in alternation one with another and together with corresponding units on the other of said airfoils.

2. A system of inflation units for aircraft comprising inflatable units arranged on port and starboard airfoils of the aircraft with a plurality of said units on each of said airfoils and each unit comprising a plurality of sets of inflatable tubes, and means for inflating sets of tubes of units on one of said airfoils in alternation with other sets of tubes of the units on that airfoil and together with corresponding sets of tubes of corresponding units on the other of said airfoils.

3. A system of inflation units for aircraft comprising inflatable units arranged on port and starboard airfoils of the aircraft with a plurality of the units on each of said airfoils said inflatable units being disposed on each airfoil at positions along the airfoil span-wise thereof, and means for operating said units in three-phase cycles each consisting of an inflation phase, a phase of exhausting to the atmosphere, and a suction phase, the operating means comprising means for inflating units on one of said airfoils in alternation one with another and together with corresponding units on the other of said airfoils in like phase therewith.

4. A system of inflation units for aircraft comprising inflatable units arranged on port and starboard airfoils of the aircraft with a plurality of the units on each of said airfoils and each unit comprising a plurality of sets of inflatable tubes, and means for operating each set of tubes in three-phase cycles each consisting of an inflation phase, a phase of exhausting to the atmosphere, and a suction phase, the operating means including means for inflating sets of tubes of units on one of said airfoils in alternation with other sets of tubes of the units on that airfoil and together with corresponding sets of tubes of corresponding units on the other of said airfoils in like phase therewith.

5. Inflation apparatus comprising an inflatable element, a pressure pump, an accumulator, means for connecting said pump alternately to said element and said accumulator for inflating the element and charging said accumulator, and means connecting said accumulator to said element at the times the pump is connected to said element to augment the supply of air under pressure to said element.

6. Apparatus for controlling the flow of air to and from an inflatable element, said apparatus comprising a pressure pump connection, an exhaust connection, an accumulator connection, valve means for putting said pump connection alternately in communication with said element and accumulator connection, and for putting said element in communication with said exhaust connection alternately with its communication with said pump connection, and snap-action, stop-motion means for moving said valve means.

7. A system of inflation units for aircraft comprising inflatable units arranged on port and starboard airfoils of the aircraft with a plurality of said units on each of said airfoils, means for inflating units on one of said airfoils in alternation one with another and means for inflating such units simultaneously with corresponding units on the other of said airfoils.

8. A system of inflation units for aircraft comprising inflatable units arranged on port and starboard airfoils of the aircraft with a plurality of the units on each of said airfoils, and means for operating said units in three-phase cycles each consisting of an inflation phase, a phase of exhausting to the atmosphere, and a suction phase, the operating means comprising means for inflating units on one of said airfoils in alternation one with another and together with corresponding units on the other of said airfoils in like phase therewith, and valve means for controlling the inflation in the cyclic operation including snap-action, stop-motion means for moving said valve means.

9. Inflation apparatus for an inflation chamber, said apparatus comprising a valve structure having intake, exhaust, and suction ports and a port for connection to said chamber, and means for operating the valve structure in three-phase cycles each consisting of an inflating phase, a phase of exhausting to the atmosphere and a suction phase, the operating means including means for moving the valve structure from a phase position to the next by snap-action and with temporary stoppage in each position.

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