

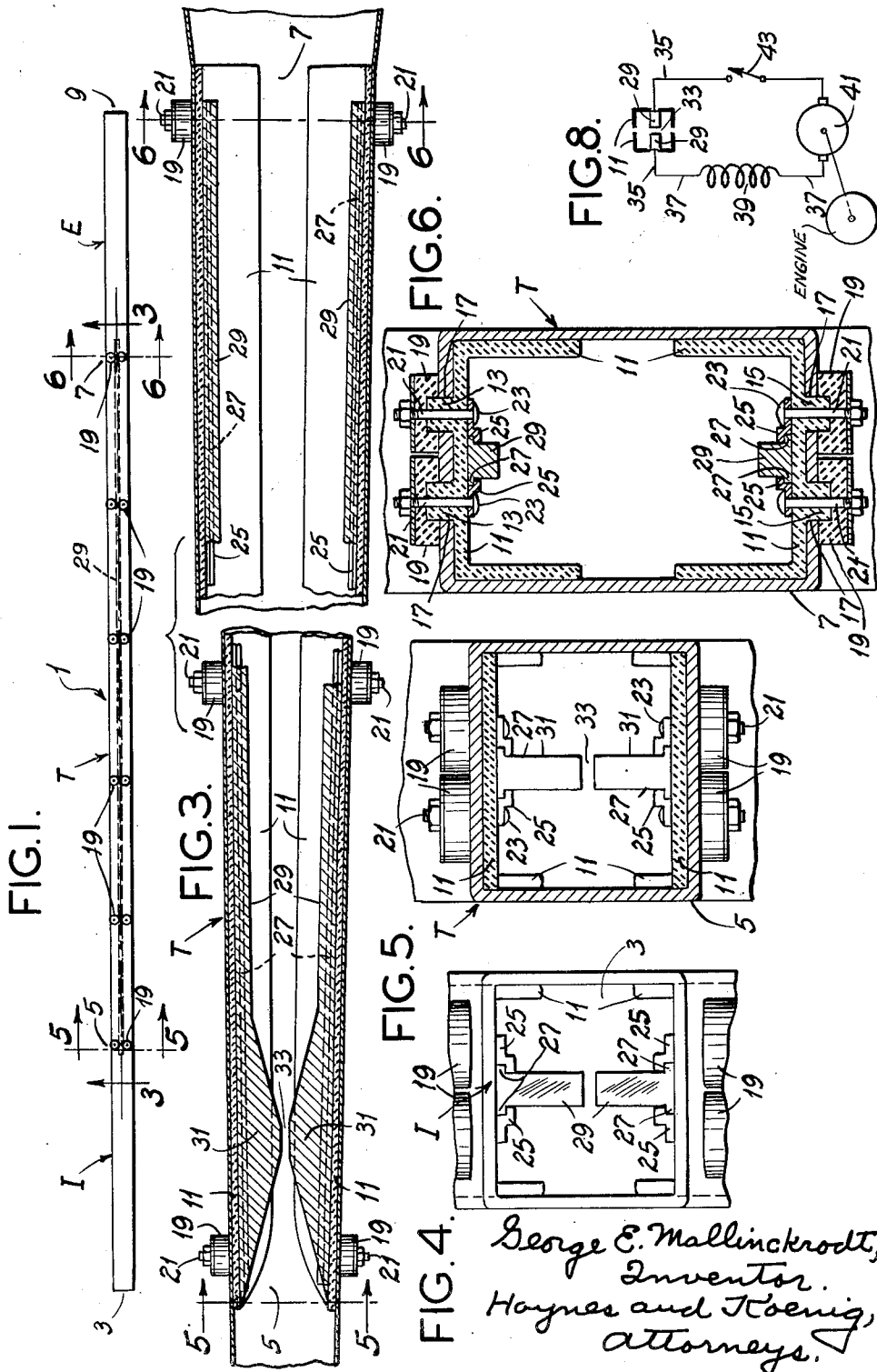
Feb. 12, 1952

G. E. MALLINCKRODT
VALVELESS PULSE JET ENGINE HAVING
ELECTRIC ARC HEATING MEANS

2,585,810

Filed Oct. 26, 1945

2 SHEETS—SHEET 1



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2 SHEETS—SHEET 2

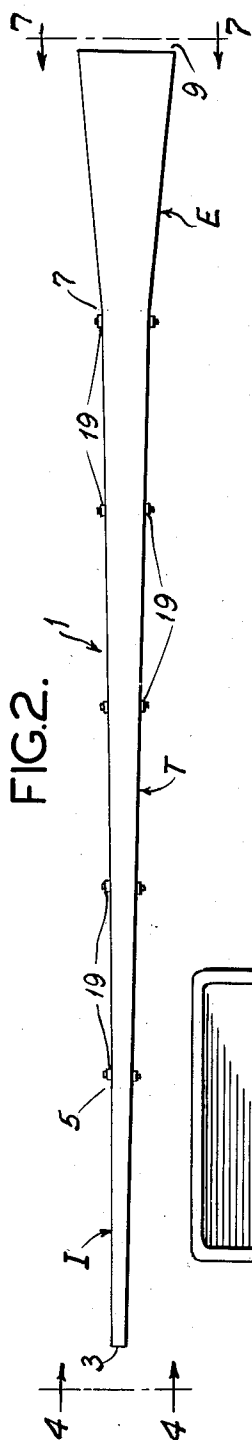


FIG. 2.

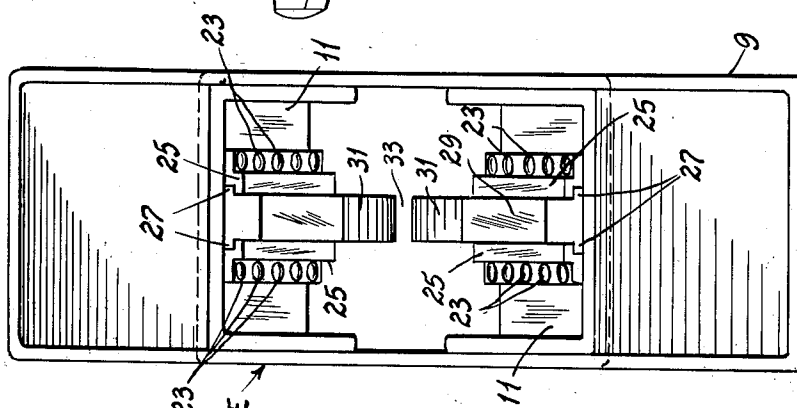


FIG. 7.

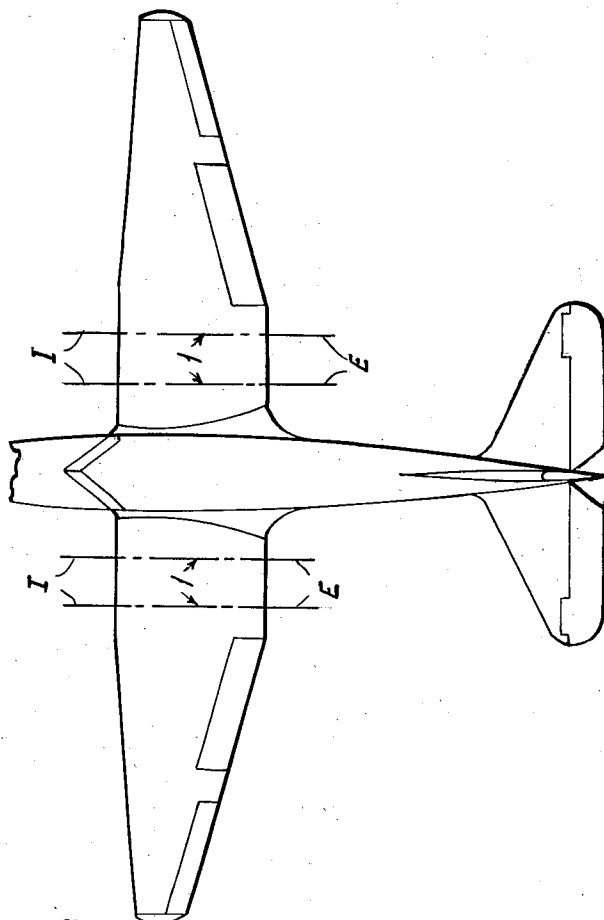


FIG. 9.

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UNITED STATES PATENT OFFICE

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6 Claims. (Cl. 60—35.5)

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This invention relates to jet propulsion apparatus, and with regard to certain more specific features, to electric arc apparatus of this class for propelling airplanes and the like.

Among the several objects of the invention may be noted the provision of a simple jet propulsion unit having no relatively moving mechanical parts; the provision of apparatus of the class described which operates at feasible temperatures, thus decreasing structural problems; the provision of a unit of the class described having substantial thrust capacity and thermodynamic efficiency; and the provision of a device of this class in which the efficiency is substantially maintained at high speeds. Other objects will be in part obvious and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which one of various possible embodiments of the invention is illustrated,

Fig. 1 is a top plan view of one jet propulsion unit;

Fig. 2 is a side elevation of Fig. 1;

Fig. 3 is an enlarged fragmentary vertical section taken on line 3—3 of Fig. 1;

Fig. 4 is an enlarged left-end view taken on line 4—4 of Fig. 2;

Fig. 5 is an enlarged vertical section taken on line 5—5 of Figs. 1 and 3;

Fig. 6 is an enlarged vertical section taken on line 6—6 of Figs. 1 and 3;

Fig. 7 is an enlarged rear end elevation viewed from line 7—7 of Fig. 2;

Fig. 8 is a circuit diagram; and

Fig. 9 is a plan view of an airplane showing how the invention is incorporated.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

Hereinafter one jet propulsion unit is described, but it is to be understood that these units may be used either singly or in multiple on airplanes and the like. For example, they may be mounted on center lines as indicated in Fig. 9. It is to be understood that the dimensions specified herein are exemplary and that variations may be made to suit particular designs.

Referring now more particularly to Figs. 1 and 2, each propulsion unit is indicated by numeral 1. Broadly, it consists of an elongate heat-resistant metal tube of increasing rectangular cross section, progressing from the front (shown at the left) to the rear (shown at the right). The width of the tube as indicated in Fig. 1 is preferably constant, for example of the order of 4

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inches. The depth as shown in Fig. 2 varies. For example, at the inlet opening 3 it is 3 in. deep. At point 5 (section 5—5) which is 4 ft. removed from the front 3, it is 3½ in. deep. At point 7 (section 6—6) which is 12 ft. behind point 5, it is 6 in. deep, and at the rear end 9, 4 ft. removed from point 7, it is 12 in. deep. All of the stated dimensions may be considered to be inside dimensions. The wall thickness is chosen to be sufficient for structural purposes.

The respective tapers between points 3, 5, 7 and 9 are preferably continuous. The section of the tube between points 3 and 5 will be referred to as an inlet nozzle or chamber I. The section between points 5 and 7 will be referred to as the energy transformation or arc chamber T. The section between points 7 and 9 will be referred to as the exhaust section E. Each unit 1 is installed in an airplane or the like with its axis parallel to the direction of motion of the airplane (see the center lines of Fig. 9). Thus the units may be located chordwise in the wings, along the fuselage, or the like. Forward motion of the airplane will cause air to be enveloped in the moving inlet section I. This inlet section I is simply an air-receiving tube which, by reason of its rearward expansive taper, reduces the friction of rearward flow to the point 5.

The upper and lower portions of the transformation section T are lined by channel-shaped, heat-resistant, insulating members 11, composed, for example, of spark-plug porcelain, mica or the like. These members have tubular lugs 13 and 15 at intervals, which extend through opening 17 in the tube T. Cupped bushings 19, composed of similar material, engage the lugs 13—15 on the outside. Fastening bolts 21 extending through the lugs 13 and bushings 19 serve to hold the liners 11 in place. Some of these bolts 21 also function as electrical terminals, as will appear.

The inside heads 23 of the bolts 21 hold conductive temperature-resistant strips 25, the edges of which are offset, as indicated, to receive flanged base portions 27 of elongate carbon strips 29 forming electrodes. The strips 25, as well as the bolts 21, are also composed of high-temperature alloy or beryllium. Other than carbon may be used for the electrodes 29, provided said other material has the requisite properties of electrodes in the described locations.

Each electrode 29 is thus insulated from the tube T and extends approximately from the point 5 to the point 7 (12 ft.). Near their front ends and just behind the point 5, the electrodes are provided with protrusions 31, leaving an approximately ¼ in. arc gap 33. An arc is struck at this gap 33 and proceeds rearwardly along the electrodes, the arc length increasing as it moves rearward to the point 7. Movement to the rear is caused by a sweep of air through the tube T from the inlet tube I. At about point 7 the extended arc becomes extinguished.

The arc is established by means of a circuit 37 such as shown in Fig. 8, wherein the terminals 35 are connections to opposite ones of said electrodes 29. Two or more of the bolts 21 may be used for the purpose. In the circuit 37 is a starting switch 43 and an inductance 39. An engine-driven A. C. generator is shown at 41. The generator 41 is one example of any suitable generator for the electrical energy required. In the present case the generator 41 is driven from a suitable engine, so marked. Circuit values are, for example, as follows:

For the generator 41, 400 cycles per second at 15,000 volts;

For the inductance coil 39, enough reactive impedance so that it, with the reactive impedance in the remainder of the circuit and generator, will total 2,300 ohms;

For the generator 41, 50 kw. at 6.5 amp.

The resistance in the arc when it becomes 3 in. long is approximately 2,300 ohms.

Operation is as follows:

It is to be assumed that the vehicle in which the jet propulsion units 1 are mounted is given an initial forward motion of, for example, approximately several hundred miles per hour in the case of the present design. This may be accomplished by means of the ordinary propeller driven from the engine which drives generator 41, or by rocket propulsion units or the like. In case a propeller is used, it may be feathered after the requisite speed is reached. In the case of the rocket propulsion unit, its action may cease at the requisite speed. The stated initial velocity is necessary for providing proper operating conditions. At the requisite speed the circuit 37 is closed at switch 43, which causes an arc initially to be struck at the $\frac{1}{4}$ in. gap 33.

Considering motions relatively to the tube 1, the sweep of air from the inlet tube I into the transformation or heater tube T causes this arc to be blown back along the electrodes 29, the arc lengthening as it recedes. Traverse of the arc is quite fast, requiring only the time necessary for air at approximately several hundred miles per hour to traverse the 12 ft. section of tube T. At or somewhat ahead of the point 7 the resistance in the arc will have become so high that the arc will be blown out. Rearward arching due to air sweep aids in the extinction process.

Assuming, as will be approximately true, that the arc operates at or near 3,500° C., it will, as it travels rearward, exert a fast heating action upon the adjacent mass and slug of air in the arc. The air therefore expands. A high air temperature approaching 3,500° C. is reached at approximately 8 ft. from the gap 33. In the last 4 ft. or so of travel in the tube T the process will be substantially isothermal at the stated temperature. When point 7 is reached and the arc becomes extinguished, the air expands further and more rapidly in the more tapered exhaust tube E, until a reduced temperature of the order of 700° C. is reached at the outlet section 9.

As the air in the arc is heated, its pressure locally momentarily increases to the order of 3 p. s. i. This pressure is of a hydrostatic nature, being exerted momentarily in all directions, both axial and radial. This pressure equilibrates the equivalent flat plate pressure of the entering air as applied to the area at the inlet 3. Equilibrium occurs ahead of the arc as the arc progresses through tube T. The distance that this point is ahead of the arc depends upon the temperature of the slug of air containing the arc. At the

temperature of the air in the arc, this distance is of the order of several inches. The stated 3 p. s. i. is approximately the operating flat plate pressure to be excepted at the inlet 3.

It is to be understood that although this 3 p. s. i. is equilibrated, the equilibrium point progresses rearward through the tube T, which allows admission of cold air immediately following the arc as the latter progresses rearward. Thus, for example, the amount of hot air contained in the arc may be of the order of 15 cu. in., which progresses rearward very quickly. Hence the walls of the tube T are subjected to extreme temperatures only for exceedingly short intervals of time.

The momentary pressure of the mass of gas under consideration also acts upon the sloping surfaces of the tube section T, thus exerting a forward axial thrust which drives the tube forward. The expanding gas passes out through the exhaust tube E in which its pressure also exerts a forward thrust by reason of the taper of tube E.

The net forward thrust is a function of the difference between the areas of the sections at points 3 and 9, multiplied by the equilibrating pressure of the heated gas (3 p. s. i.) during the part of the cycle when inflow of additional air occurs, as it follows in to the rearwardly moving equilibrium point. Some resistance is built up against the free entry of cold air by the fact that, as heating occurs in the rearwardly moving arc, the equilibrium point is shifted forward relative to the arc, due to the expansion of the air with increasing temperature. As the rearwardly traveling mass of air in the arc expands, it resists the incoming air, applying an opposite impulse to the mass of air behind it.

As the pressure in the tube T decreases after the arc has been extinguished, the flat plate pressure at the transient equilibrium point will become unbalanced and a fresh charge of cool air will have filled the tube T. By this time the arc, which in the previous cycle has been extinguished at point 7, will have been automatically reestablished at the gap 33. Thus the conditions are fully reestablished for a succeeding cycle. Cyclic action is then continuously repetitious, the timing of the arc and of air entry and expansion all being inherent in the process. No moving parts are required for the pulse or expansion process or its timing, no valves of any kind being used.

If the internal pressure in tube T is lower than the equivalent flat plate pressure at inlet 3, the optimum efficiency is not attained but the device is still mechanically operative. In fact, by this means thrust may be controlled.

The tube under repeated thrust or pulsing will accelerate along its axis until the average forward thrust will be equilibrated by frictional resistance, after which a constant velocity condition will inhere. Velocity is controlled by controlling the electrical energy input into the arc.

Although a very high temperature exists in the mass or slug of air in the arc, it is not to be assumed that the parts of the tubes T and E attain any such temperatures. In fact, the tube walls are exposed to high temperatures for only very short intervals of time and to the low temperatures of the incoming air for much longer intervals of time. Since the weight ratio of the cool incoming air to the hot air in the arc is of the order of 1,000:1, this means, assuming that the incoming air is at 0° C., that the walls

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of the apparatus will never reach temperatures destructive of even the most commonly available materials for the tube, such as, for example, aluminum. This also accounts for the ability of the apparatus to reach high efficiencies, because the temperature to which the arc may be raised is not limited by the structural materials composing the tube and contained parts.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A jet propulsion unit comprising an elongate tapering thrust chamber having a leading inlet and a larger trailing outlet, movement of the unit introducing relatively cool gaseous medium through the inlet into said chamber, electrodes extending substantially along the length of the chamber from a first arc-striking point near the inlet to a second arc extinguishing point near the outlet for drawing an arc at said first point in the presence of said medium, whereby the medium is heated and ejected from said outlet, said medium due to relative movement between it and the thrust chamber moving the arc from the first point near the inlet to the second point near the outlet along the electrodes, the spacing of the electrodes near the outlet being sufficient to attenuate the arc to extinction as it reaches said second point near the outlet.

2. A jet propulsion unit comprising an elongate tapering thrust chamber having a leading inlet and a larger trailing outlet, a movement of the unit along its length introducing relatively cool gaseous medium through the inlet into said chamber, electrodes extending along the length of the chamber and being spaced closer together toward the inlet than toward the outlet for striking an arc at said closer spacing in the presence of said medium, whereby the medium is heated and ejected from said outlet, said medium due to relative movement between it and the thrust chamber moving the arc from the inlet along the electrodes and toward the outlet.

3. A jet propulsion unit comprising an elongate tapering thrust chamber having a leading inlet and a larger trailing outlet, movement of the unit introducing relatively cool gaseous medium through the inlet into said chamber, electrodes extending along the length of the chamber and being increasingly spaced toward the outlet for drawing an arc at their closer spacing in the presence of said medium whereby the medium is heated and ejected from said outlet, said medium due to relative movement between it and the thrust chamber moving the arc from the inlet to the outlet, said electrodes being closer together near the inlet to strike and maintain the arc as it is moved and being far enough apart near the outlet to attenuate it to extinction.

4. A jet propulsion unit comprising a tubular arc chamber tapering outwardly from the front to the rear, said chamber having a forward gas inlet and a rearward gas outlet, elongate electrodes located in said arc chamber which are increasingly spaced from front to rear, circuit means for applying current to said electrodes, said electrodes extending from a point of relatively close proximity whereat an arc is automatically

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struck by said circuit means, said electrodes extending to points of relatively greater spacing where said arc becomes longer to the point of extinction, substantially forward velocity of the chamber introducing gas into said inlet to said arc to sweep the latter to a point where it will be extinguished, said arc momentarily heating the introduced gas to expand it temporarily to resist entrance of further gas into the inlet and simultaneously by impingement upon the tapering chamber to apply an axial forward thrust to said chamber.

5. Jet propulsion apparatus comprising a moving arc chamber having a leading inlet and a trailing outlet, said chamber being tapered outward from the inlet to the outlet, elongate electrodes extending from a relatively narrow gap toward the inlet to a relatively wider gap toward the outlet, the movement of the chamber serving to introduce air into the chamber through said inlet and to move the air rearward through the chamber, means for striking an arc at said relatively narrow gap, said arc heating and expanding the air whereby its pressure momentarily increases, movement of the contained air toward the outlet serving to move and attenuate the arc until it breaks, pressure of the air on the tapered chamber serving to thrust the tapered arc chamber forward, said extinguished arc being automatically restruct at the narrow gap as additional air enters the inlet under the reduced pressure in said arc chamber.

6. A jet propulsion unit comprising an elongate tubular member flaring from front to rear and having a front gas inlet and a rear gas outlet, said tubular member having a front inlet section of one taper, an intermediate section of greater taper, and a rear section of still greater taper, axially extending electrodes in said intermediate chamber, said electrodes being closely spaced at their forward ends to form a short gap and being increasingly spaced from one another in the rearward direction toward a long gap, circuit means supplying current to said electrodes, the electrical values associated with said current being such as automatically to strike an arc at the short arc gap and to permit said arc to break after traverse backward along the electrodes to the long gap, forward motion of the tubular member effecting introduction of air to blow said arc from said gap to the point of extinction, said gas expanding against the flaring tubular member to effect a forward thrust thereon.

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