Feb. 7, 1967 B. C. DOXEY 3,302,886

JET PROPULSION MOTORS

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Fig. 1

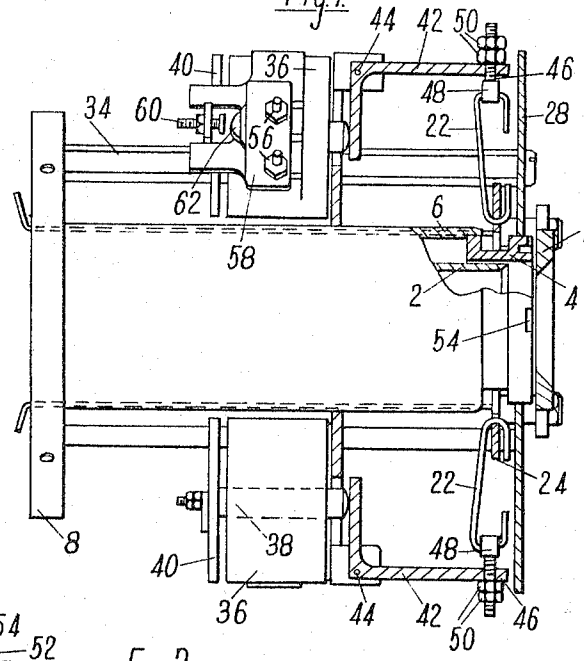


Fig. 1A.

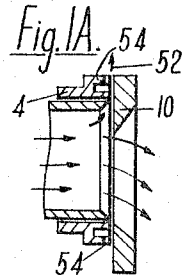
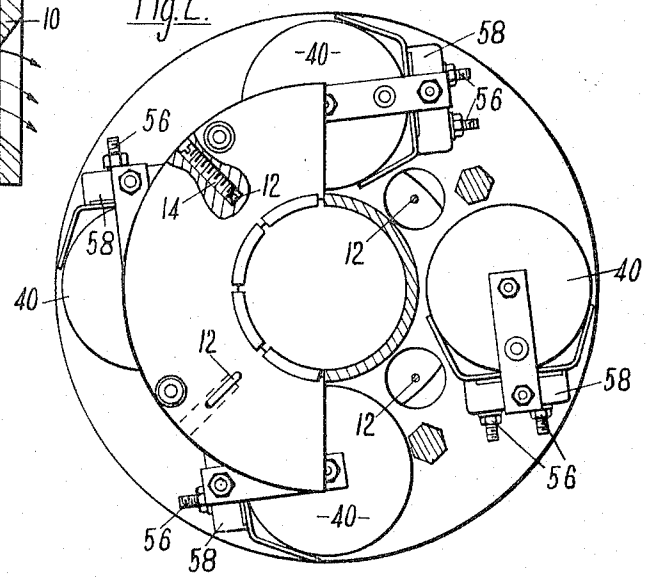


Fig. 2.



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Fig. 3.

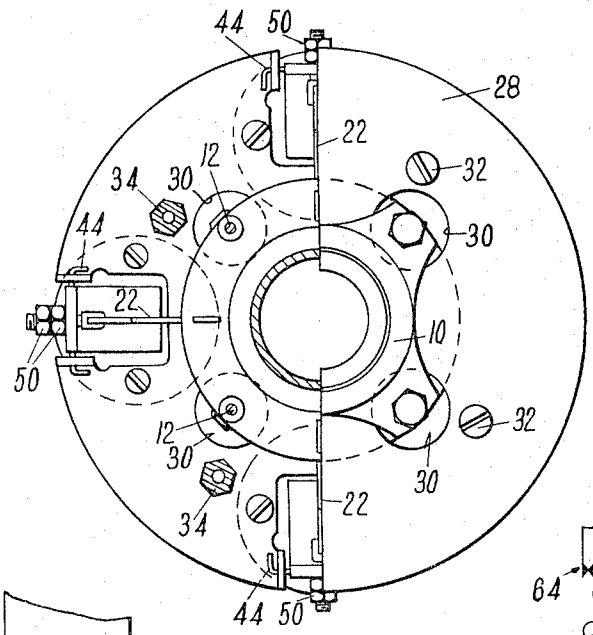


Fig. 7.

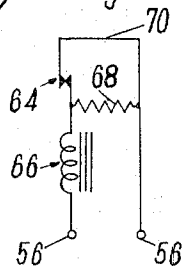


Fig. 4.

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Fig. 5.

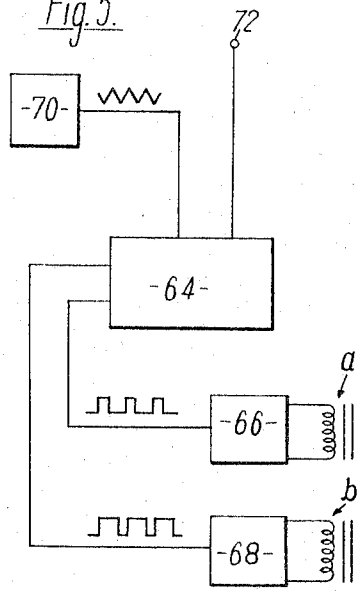


Fig. 6A.

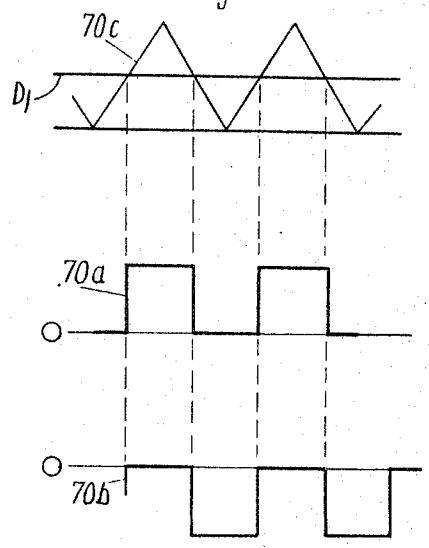


Fig. 6B.

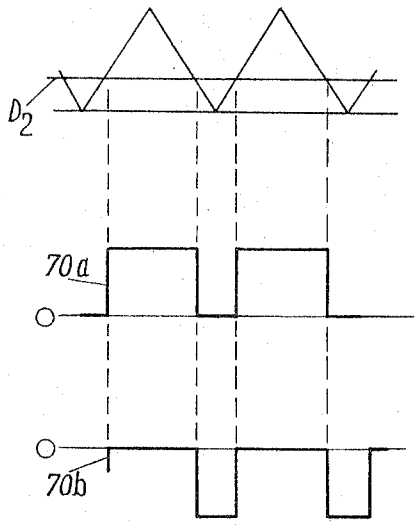
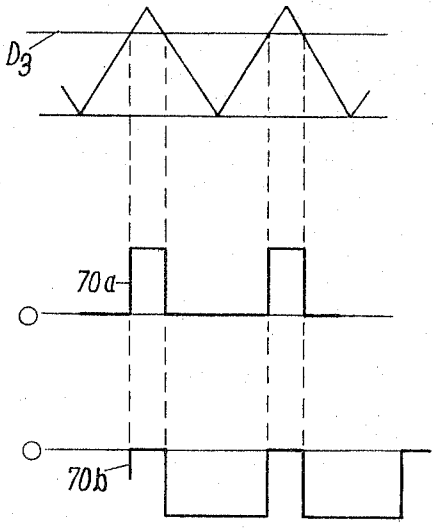


Fig. 6C.



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Fig. 8.

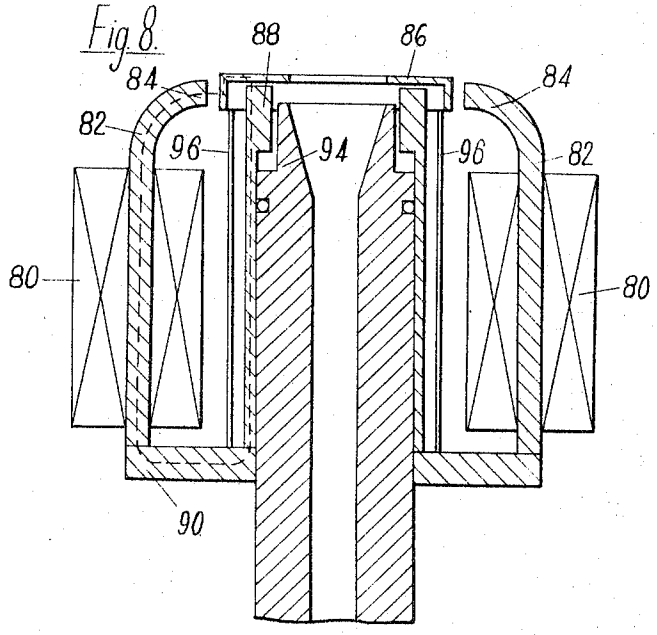
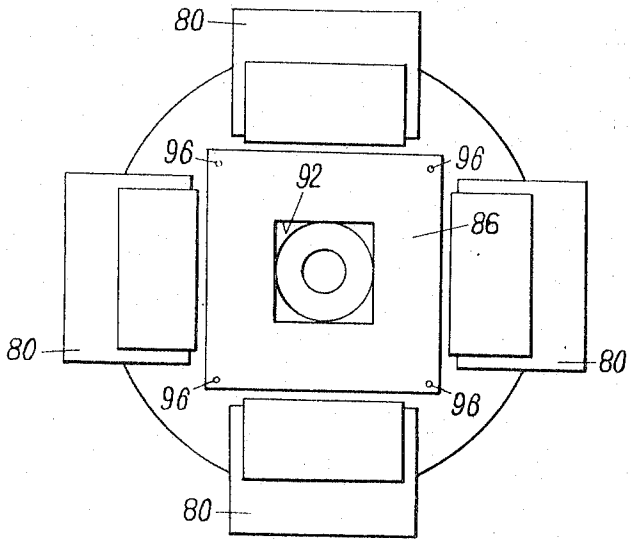


Fig. 9.



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3,302,886

JET PROPULSION MOTORS

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Claims priority, application Great Britain, Dec. 3, 1963, 47,722/63
8 Claims. (Cl. 239—265.19)

This invention relates to jet-propulsion motors useful particularly for guided missiles. In particular, it is concerned with a method of providing directional control of a guided missile by causing a side thrust to be produced by deflecting the efflux of the motor, which would normally be a rocket motor.

According to this invention a jet-propulsion motor has immediately behind its discharge nozzle a jet deflector comprising a plate with a hole having a central axis which is co-axial with the discharge nozzle when in the neutral position (that is to say, with no jet deflection), the deflector plate being carried by a number of parallel flexible wires extending forwards from the plate to anchorages on the motor, and the motor includes means for moving the plate laterally with respect to the nozzle so as to deflect the jet in any desired direction.

Lateral control of the deflector plate is preferably achieved by means of electromagnets. For example, there may be four electromagnets evenly spaced around the motor nozzle, so that the deflector plate can be moved laterally along two paths at right angles to one another, in either direction. In a preferred arrangement the electromagnets are arranged with their axes parallel to the axis of the nozzle, and they act through bell-cranks with links connected to the deflector plate.

Control of the deflector plate through four electromagnets is preferably carried out on the "bang-bang" principle. That is to say, considering one pair of opposed electromagnets, the electromagnets are magnetised alternately at a constant mean frequency, the respective times of energisation of the two electromagnets being varied so as to vary the mean lateral position of the deflector plate. In other words, the deflector plate oscillates in two lateral directions at right angles to one another, so that the mean position of its axis may be displaced laterally from the axis of the nozzle in any direction; the neutral position of the deflector plate is achieved when, considering each opposed pair of electromagnets, the times of energisation of the two electromagnets are equal.

Examples of jet-propulsion motor nozzles according to this invention are shown in the accompanying drawings. In these drawings:

FIGURE 1 is a side view, partly sectioned, of one example;

FIGURE 1A is a fragmentary side view showing the deflector plate in the jet-deflection position;

FIGURE 2 is an end view from the left of FIGURE 1, partly broken away;

FIGURE 3 is an end view from the right of FIGURE 1, also partly broken away;

FIGURE 4 is a fragmentary side view showing how one of the wires carrying the deflector plate is secured to the plate and to the motor anchorage;

FIGURE 5 is a block diagram showing the electrical circuit;

FIGURES 6A, 6B and 6C show the voltages applied to two opposed solenoids in different conditions;

FIGURE 7 shows a small part of the electrical circuit;

FIGURE 8 is a sectional side view of a second example; and

FIGURE 9 is an end view from the top of FIGURE 8.

The discharge nozzle in the first example is defined by

a tube 2 contained within a housing consisting of an end portion 4 and a tubular part 6 which is connected to a flange 8 to be bolted to the remainder of the motor (not shown). During use the tube 2 expands so that its end reaches the end of the portion 4, as shown in FIGURE 1A.

Immediately behind the discharge nozzle there is a deflector plate 10 which is carried by four parallel steel wires 12. Each wire has the front end anchored in a hole in the flange 8 by a screw 14 (see FIGURE 4), and has its rear end brazed in an externally threaded part 16. A nut 18 is tightened on the thread of the part 16 and, together with a flange 20 on the part 16, serves to secure the wire to the plate 10. Lateral movement is transmitted to the deflector plate by four links 22 which have their inner ends hooked through holes in a ring 24 secured to the plate 10 by brazing, with an interposed spacing tube 26 around each threaded part 16.

A heat shield 28, for example of molybdenum, isolates from the heat of the discharge jet most of the moving parts of the mechanism, the main exception being the deflector plate 10, which is made of a heat-resisting material such as molybdenum or tungsten. The heat shield 28 has openings 30 through which the spacing tubes 26 connecting the deflector plate to the ring 24 can pass. Four screws 32 secure the heat shield 28 to four parallel pillars 34 carried by the front flange 8.

Lateral control of the deflector plate 10 is achieved by means of four electromagnets 36 which are evenly spaced around the motor and lie with their axes parallel to the axis of the nozzle. Each electromagnet consists of a solenoid containing a plunger 38 carrying an armature 40. When any given solenoid is energised, its armature 40 is attracted to the solenoid, that is to say pulled to the right as seen in FIGURE 1; the right-hand end of the plunger then rotates a bellcrank 42 about its pivot 44 so as to move the rear end 46 of the bellcrank away from the axis of the nozzle, and the rear end 46 carries with it the link 22 which pulls the ring 24 laterally and consequently pulls also the deflector plate 10. Each link 22 has its outer end hooked through a hole in a threaded member 48 anchored to the bellcrank by nuts 50. Adjustment of all the nuts 50 enables the deflector plate to be set accurately in the neutral position (that is to say, with its central axis aligned with the axis of the nozzle) when the solenoids are all unmagnetised.

FIGURE 1A shows the deflector plate at the limit of its lateral travel in one direction and shows how the plate then acts to deflect the discharge jet slightly in the lateral direction in which the plate has been moved. A small amount of flow in the opposite direction escapes through a slight clearance gap between the plate 10 and the end portion 4, this flow being represented by the arrow 52; the escape of the fluid flow 52 is facilitated by one of four slots 54 in the end portion 4.

Electrical connection to each solenoid is made through two terminals 56 on a switch housing 58 mounted on the solenoid. When the armature 40 is attracted to the solenoid, it carries with it a switch-operating member in the form of an adjustable screw 60 which engages a switch actuator 62 and thus opens the switch. As a result, the current passed through the solenoid is reduced. The circuit for achieving this for each solenoid is shown in FIGURE 7. It will be seen that, when the switch 64 is closed, a current will pass through the solenoid winding 66 via a resistor 68 and a resistor by-pass 70, but when the switch 64 is opened as a result of engagement of the screw 60 with the actuator 62, the impedance across the terminals 56 increases and the current through the solenoid winding 66 therefore decreases. This decreased current is still sufficient to hold the armature 40 against the solenoid; the increased current is needed only to attract the armature 40 initially to the solenoid from the posi-

tion shown in FIGURE 1. The screw 60 is adjusted so as to engage the actuator 62 and open the switch just as the armature 40 reaches the solenoid.

The electromagnets are operated on the bang-bang principle. Considering one pair of opposed electromagnets controlling the position of the deflector plate along one path, the electromagnets are magnetised alternately at a constant mean frequency of, for example, 20 cycles per second, the respective times of energisation of the electromagnets being varied so as to vary the mean lateral position of the deflector plate. FIGURE 5 is a block diagram showing the electrical circuit for controlling two opposed electromagnets.

As shown in FIGURE 5, the two electromagnets, represented in this figure by the letters A and B, are fed with rectangular wave signals from a bi-stable unit 64 through output stages 66 and 68. The bi-stable unit 64 is powered by a triangular wave generator 70 and is controlled by a direct current bias signal fed through a terminal 72. FIGURES 6A, 6B and 6C show how the triangular wave 70*c* from the generator 70 is converted by the bi-stable unit into two rectangular waves 70*a* and 70*b* which are fed respectively to the output stages 66 and 68. When a direct current bias signal D1, equal to half the peak voltage of the triangular wave 70*c*, is fed to the bi-stable unit (see FIGURE 6A), the bias signal triggers the bi-stable unit at regular intervals, and the result is that the signals 70*a* and 70*b* fed to the electromagnets *a* and *b* are both square waves; the two electromagnets are therefore energised for the same periods, and the deflector plate takes up a mean position in which its axis has zero lateral displacement. When a lower bias signal D2 is fed to the bi-stable unit (see FIGURE 6B) the bi-stable unit is triggered in such a way that the electromagnet *a* is magnetised for long periods by the signal 70*a*, while the electromagnet *b* is magnetised for short periods by the signal 70*b*; consequently the deflector plate will take up a mean position in which its axis is laterally displaced towards the electromagnet *a*. On the other hand, if a bias signal D3 (see FIGURE 6C) which is larger than the signal D1 is fed to the bi-stable unit then the electromagnet *a* is magnetised for short periods, while the electromagnet *b* is magnetised for long periods; consequently, the mean position of the deflector plate will be with its axis displaced laterally towards the electromagnet *b*. The direct current bias signal can be varied between a value zero and a value equal to the peak voltage of the triangular wave (i.e. twice D1). A zero bias signal gives a maximum displacement of the deflector plate in one direction, in which case there is no actual reciprocation of the deflector plate, and the maximum bias signal gives the maximum displacement of the deflector plate in the other direction, again with no actual reciprocation of the deflector plate.

The switch-operated circuit for reducing the current through each electromagnet after the initial pulling of the armature 40 towards the electromagnet, as shown in FIGURE 7, is incorporated between the output stage 66 or 68 and the electromagnet.

As an alternative to the circuit shown in FIGURE 7 for reducing the current through the electromagnet, the switch on each electromagnet may, on being engaged by the actuator, reduce the current by switching from an initial relatively high voltage to a lower voltage.

The two pairs of electromagnets require separate bi-stable units and separate bias signals, but they may be powered by a single triangular wave generator. Alternatively, there may be two separate triangular wave generators which may operate at different frequencies. For example, one pair of electromagnets may be controlled by a signal at 20 cycles per second and the other pair may be controlled by a signal at 10 cycles per second. The choice of frequency will depend upon the nature of the control required respectively from the two pairs of electromagnets.

The triangular wave generator and the bi-stable unit are known in themselves. Suitable circuits are described in the Mullard Pulse Circuit Hand Book.

A different means of controlling the deflector plate is shown in FIGURES 8 and 9. In this example there are four solenoids 80 wound around four parallel strips of magnetic material 82 turned inwards at their trailing ends 84. When any particular solenoid is energised, it attracts a deflector plate 86 towards it, the deflector plate being of magnetic material or having parts of magnetic material (not shown) attached to it. The magnetic circuit is completed by a sleeve 88 and a flange 90.

The deflector plate is square, as shown in FIGURE 9, and it has a square opening 92. The drawings show the deflector plate in the neutral position, with the centre of the square opening 92 lying on the axis of the discharge nozzle 94, which has a bore of circular cross-section. The deflector plate is carried by four parallel steel wires 96 which are secured to the plate at its four corners and are anchored to the flange 90.

I claim:

1. A jet propulsion motor having a discharge nozzle, a jet deflector plate mounted immediately behind the discharge nozzle, means defining a hole in the deflector plate having a central axis co-axial with the discharge nozzle when the said plate is in a neutral position, a plurality of parallel flexible wires connected to the deflector plate and extending forwards from the plate, means on the motor for anchoring the forward ends of the wires, and means for moving the deflector plate laterally with respect to the nozzle for deflecting the jet discharge in any desired direction.

2. A motor according to claim 1, in which the means for moving the deflector plate laterally comprises a plurality of electromagnets.

3. A motor according to claim 2, in which there are four of the said electromagnets which are spaced evenly around the motor discharge nozzle, the deflector plate being movable laterally along two paths at right angles to one another, in either direction, the paths extending between opposed electromagnets.

4. A motor according to claim 3, in which the said electromagnets have axes parallel to the axis of the discharge nozzle, and act through bell-cranks with links connected to the deflector plate.

5. A motor according to claim 3, in which the electromagnets operate on a bang-bang principle, the motor including means for magnetising opposed electromagnets alternately at a constant mean frequency, the respective times of energisation of the two electromagnets being controllable to vary the mean lateral position of the deflector plate.

6. A motor according to claim 2, including switches on the electromagnets with means for operating the switches when the deflector plate has been fully displaced in any given direction by an operative electromagnet, the effect of the switching being to reduce the current through the operative electromagnet.

7. A motor according to claim 1, including a heat shield surrounding the discharge nozzle immediately in front of the deflector plate to shield the plate-controlling mechanism from the heat of the jet.

8. A jet propulsion motor having a discharge nozzle including a central axis, a jet deflector plate mounted immediately behind the discharge nozzle, means defining a hole in the said plate having a central axis which is co-axial with the discharge nozzle when in a neutral position, a plurality of parallel flexible wires secured to the plate and extending forwards from the plate, means on the motor for anchoring the forward ends of the wires, four electromagnets which are evenly spaced around the discharge nozzle to form two pairs of opposed electromagnets, each electromagnet having means defining a central bore lying parallel to the axis of the discharge nozzle and containing a plunger within the bore, each plunger carry-

ing at its forward end an armature which is attracted to the electromagnet when the electromagnet is energised, to move the plunger rearwards within the bore, each plunger abutting with its rear end against a bell-crank which is connected by means of a link to a ring secured to the deflector plate, the motor including means for energising the opposed electromagnets of each pair alternately at a constant mean frequency, and including means for varying the respective times of energisation of the two

electromagnets of each pair, to vary the mean lateral position of the deflector plate.

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EVERETT W. KIRBY, *Primary Examiner.*