United States Patent

[11] 3,604,628

[72] Inventor **William D. Haynie, Jr.**
Lake Park, Fla.

[21] Appl. No. **846,772**
[22] Filed **Aug. 1, 1969**
[45] Patented **Sept. 14, 1971**
[73] Assignee **United Aircraft Corporation**
East Hartford, Conn.

[54] **SKEWED EXIT PLANE NOZZLE SYSTEM FOR OPTIMUM THRUST**
8 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **239/265.25,** 239/587, 239/598, 239/601, 60/271, 244/56
[51] **Int. Cl.** **B64c 15/02**
[50] **Field of Search** 239/265.19, 265.25, 265.27, 265.33, 265.35, 587, 598, 599, 601; 60/224, 232, 271; 244/55, 56

[56] **References Cited**

UNITED STATES PATENTS

3,057,581	10/1962	Tumavicus	244/55 X

FOREIGN PATENTS

960,106	6/1964	Great Britain	239/265.25

Primary Examiner—M. Henson Wood, Jr.
Assistant Examiner—Michael Y. Mar
Attorney—Jack N. McCarthy

ABSTRACT: A nozzle arrangement formed by mounting a plurality of nozzles at the rear of a vehicle. Each nozzle being mounted for pivotal movement in a radial plane. Each nozzle is truncated at an angle other than 90° to the flow direction at the nozzle exit, whereby a skewed exit plane is formed. Control means are provided to rotate the nozzles about their mounting axes to obtain maximum performance for the ambient pressure the nozzle is operating in.

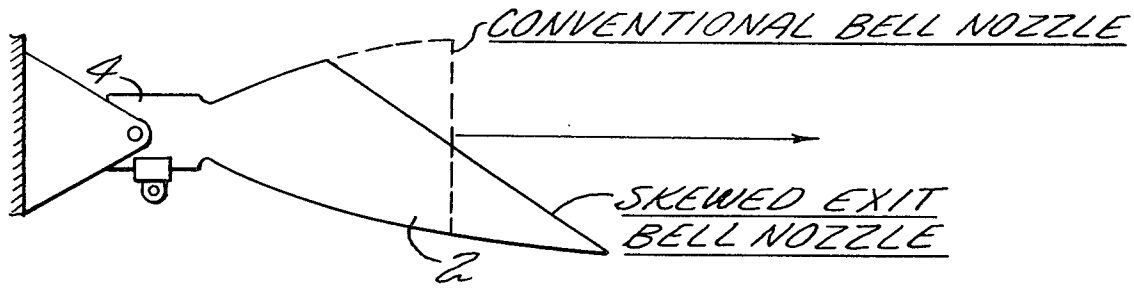


FIG. 1

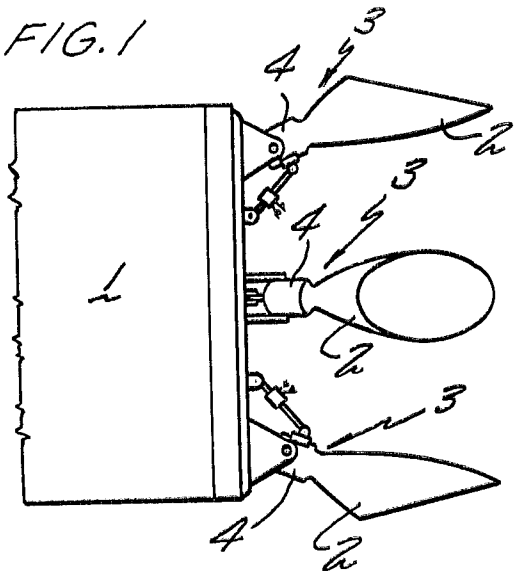


FIG. 3

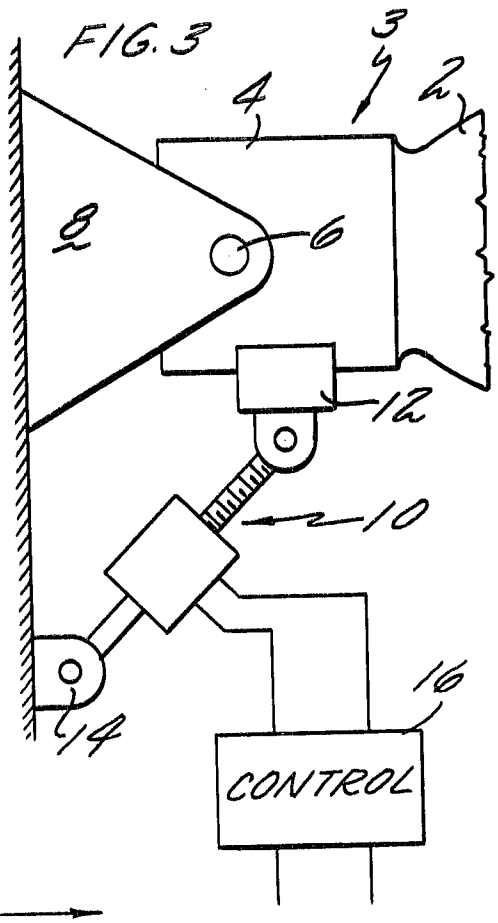


FIG. 2A

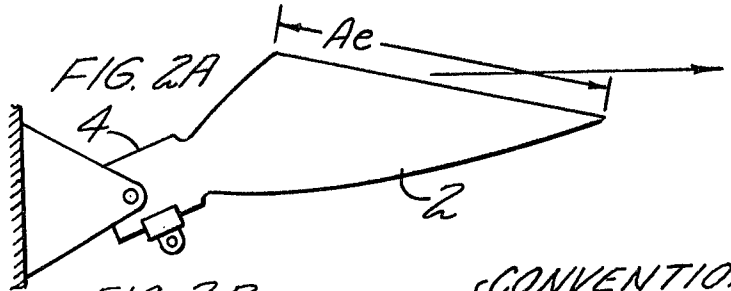


FIG. 2B

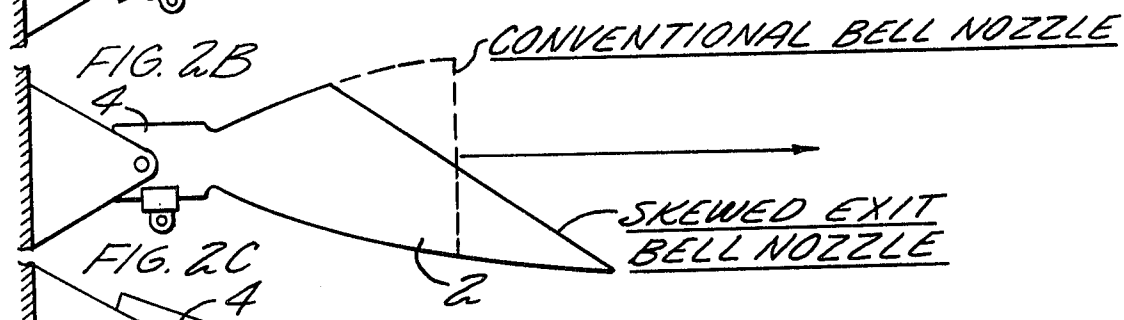
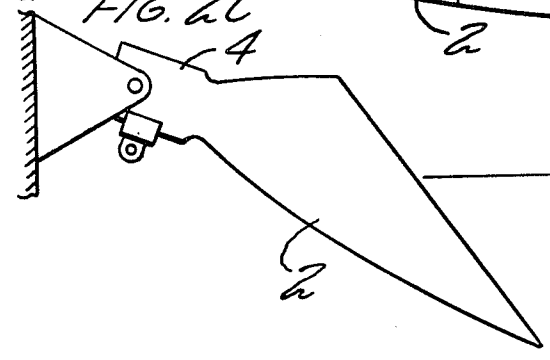


FIG. 2C



INVENTOR
WILLIAM D. HAYNIE, JR.
BY Jack N. M. Cathey
AGENT

FIG. 4

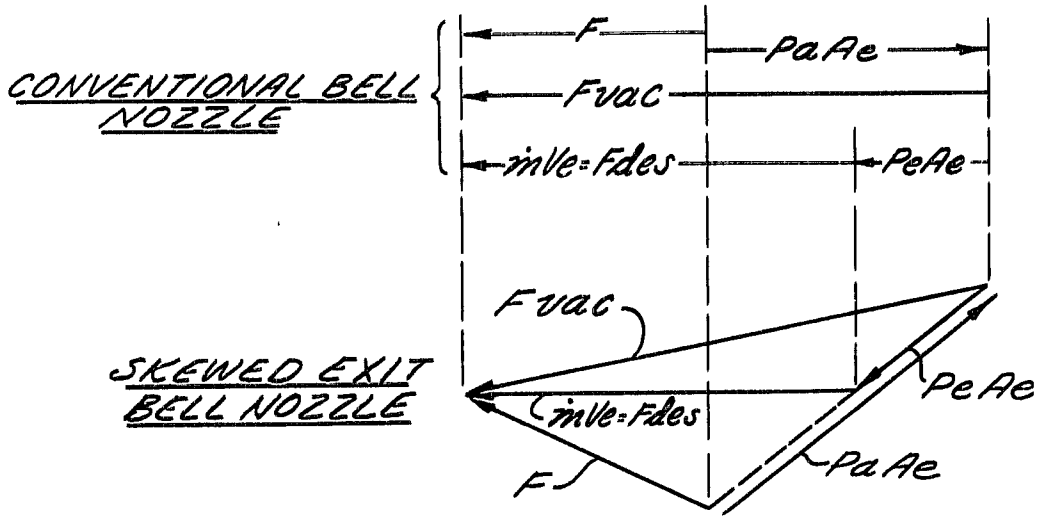
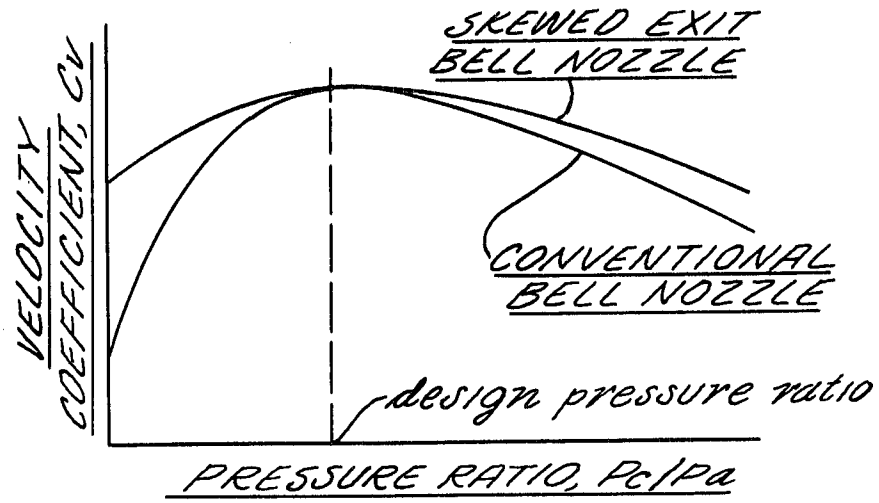

CONVENTIONAL BELL NOZZLE
F
PaAe
Fvac
mVe=Fdes
PeAe
SKEWED EXIT BELL NOZZLE
Fvac
PeAe
mVe=Fdes
F
PaAe

FIG. 5


SKEWED EXIT BELL NOZZLE
VELOCITY COEFFICIENT, Cv
CONVENTIONAL BELL NOZZLE
design pressure ratio
PRESSURE RATIO, Pc/Pa

SKEWED EXIT PLANE NOZZLE SYSTEM FOR OPTIMUM THRUST

BACKGROUND OF THE INVENTION

This invention relates to nozzles and more particularly to a cluster of nozzles to obtain a greater performance over a range of operating conditions. Mechanical means to mount the engines such as shown in FIG. 1 is shown in U.S. Pat. No. 3,057,581.

SUMMARY OF INVENTION

An object of this invention is to provide a nozzle combination having means for compensating for losses incurred by conventional bell nozzles when operated over a range of ambient pressures. This nozzle combination will maintain a high efficiency over a wide range of pressure ratios. Each nozzle of the combination is truncated so as to have a skewed exit plane and the skewed exit nozzles are placed so that the plane of the exit of each nozzle is located perpendicular to a radial plane through the vehicle in which it can move. Another aspect of this invention is control means for rotating each skewed exit nozzle to place the direction of thrust from each nozzle so that it is parallel to the longitudinal axis of the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of the rear end of a vehicle with the skewed exit nozzles positioned having a small projected exit area.

FIG. 2 is a view of a single skewed exit nozzle mounted in position for a low altitude.

FIG. 2B is a view of a single skewed exit nozzle mounted in position for an intermediate altitude.

FIG. 2C is a view of a single skewed exit nozzle mounted in position for a high altitude.

FIG. 3 is an enlarged view showing the mounting for a rocket engine and skewed exit nozzle with control means for rotating the engine and nozzle.

FIG. 4 is a view comparing vector diagrams for a conventional bell nozzle and skewed exit bell nozzle when in the position shown in 2B.

FIG. 5 is a graph showing the performance of a conventional bell nozzle and skewed exit bell nozzle with the velocity coefficient C_r being plotted against pressure ratio P_e/P_a.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1 a rocket and nozzle arrangement is shown mounted on the rear or underside of a vehicle 1 for propelling the vehicle. This arrangement includes a cluster of four rocket engine and nozzle combinations 3, each mounted 90° apart around the outer circumference of the vehicle. Each rocket engine and nozzle combination includes a rocket engine 4 and nozzle 2. Each rocket engine and nozzle combination 3 is pivotally mounted for movement in a radial plane. Trunnions 6 project from each side of each rocket engine 4 and are mounted for rotation in sets of brackets 8 which extend from the rear of the vehicle 1.

Each nozzle 2 is truncated in a like manner at an angle of less than 90° to the longitudinal axis of the rocket engine and nozzle combination. It can be seen that the nozzle exit plane is inclined at an angle to the exit flow direction. This angle should be in the range of from 15° to 45° to achieve the greatest degree of control. The exit opening of each nozzle 2 is formed in a nozzle exit plane and this plane is maintained perpendicular to the radial plane which extends through the longitudinal axis of the vehicle 1 and the longitudinal axis of its respective engine and nozzle combination.

Means for pivotally actuating each rocket engine and nozzle combination 3 are provided which comprise a moveable link 10 pivotally connected at one end to a bracket 12 on the rocket engine and at its other end to a bracket 14 on the vehicle. This link can be either hydraulically or electrically actuated to lengthen or shorten it.

Control 16 is provided which will move each link the length necessary to alter nozzle positions to place them at their desired optimum position for a sensed ambient pressure. If an intermediate ambient pressure is sensed by the control 16, it will actuate the moveable links 10 so that the engine and nozzle combination 3 will be placed in a position such as shown in FIG. 2B. As ambient pressure decreases, indicating an increase in altitude, the control 16 will move each of the engine and nozzle combinations 3 so that they will present a greater projected area to the rear and have the resultant thrust parallel to the axis of the vehicle 1. If the vehicle is at low altitudes, thereby sensing higher ambient pressures, each engine and nozzle combination 3 is placed so that a small projected area is presented with the resultant thrust still parallel to the axis of the vehicle 1.

Control 16 is an ambient pressure operated device which is programmed to position the engine nozzle combinations 3 at a given angle for each ambient pressure. If the vehicle altitude changes the control 16 will sense the change in ambient pressure and rotate each engine nozzle combination 3 accordingly. A control, sensing ambient pressure and having a programmed output in response thereto, is not part of this invention and is a control well within the skill of the control art. At high ambient pressures the nozzles are positioned to present a small projected exit area as shown by FIG. 2, and at low ambient pressures the nozzles are positioned to present a large projected exit area as shown in FIG. 2C.

In a regular bell nozzle the standard thrust equation is as follows:

$$F=\dot{m}\,V_e+P_eA_e-P_aA_e$$

Where:

F = thrust

$\dot{m}$ = mass flow

V_e = exit velocity

P_e = exit pressure

A_e = area of exit

P_a = ambient pressure

In applying this formula to the skewed exit bell nozzle 2, it must be noted that the pressure at the exit plane P_eA_e, acts in a direction normal to the exit area A_e. Similarly, the ambient force P_aA_e also acts normal to the exit area but opposite in direction to P_eA_e. The vector diagrams for three different operating conditions are shown in FIG. 4, for both the skewed exit bell nozzle and the conventional bell nozzle.

The vector F_{vac} shows the size and direction of the force at vacuum, F_{des} shows the size and direction of the force of the nozzle at its design altitude where the pressure area thrust (P_eA_e) of the nozzle is equal to the ambient pressure force (P_aA_{ea}) and F shows the size and direction of the force of the nozzle below said design altitude of the nozzle. It will be noted that while the design thrust (F_{des}) is the same, the amount of the F_{vac} is greater for the skewed exit bell nozzle and the amount of the thrust F is greater for the skewed exit bell nozzle. However, since these vectors do not have a proper direction to obtain the greatest benefit, the nozzles are therefore pivotally moved until the vectors are parallel to the axis of the vehicle. Maximum axial thrust is obtained this way.

It can be seen in FIG. 5 that at the design pressure ratio the conventional bell nozzle and skewed exit bell nozzle both have the same velocity coefficient. However, if the pressure ratio increases or decreases, the skewed exit bell nozzle maintains a higher velocity coefficient. It is to be noted that FIG. 5 is also derived from analytical calculations and that for actual operations it is believed that the performance of the skewed exit bell nozzle might be slightly lower than that of the conventional bell nozzle at the design pressure ratio.

I claim:

1. In combination, a vehicle having an axis, nozzle means for providing thrust for said vehicle, said nozzle means including a skewed exit nozzle having a longitudinal axis and an inclined exit plane, said skewed exit nozzle being mounted for pivotal movement with said exit plane remaining perpendicular to a plane passing through said axis of said vehicle and

through said longitudinal axis of said skewed exit nozzle during movement.

2. In combination, a vehicle having an axis, nozzle means mounted on said vehicle for providing thrust for said vehicle, said nozzle means including a skewed exit nozzle, said skewed exit nozzle having a longitudinal axis and an exit having an inclined exit plane, said skewed exit nozzle being pivotally mounted for movement to different positions for different altitudes to vary the projected area of the exit in the direction of thrust from a minimum area at low altitude to a maximum area at high altitude.

3. A combination as set forth in claim 2 wherein control means are provided to position said nozzle means to maintain the direction of thrust parallel to the axis of said vehicle.

4. A combination as set forth in claim 1 wherein said nozzle means includes a plurality of skewed exit nozzles, said skewed exit nozzles being mounted around the axis of said vehicle control means for moving said nozzle means together maintaining said exit planes thereof at the same angle with respect to the axis of said vehicle.

5. A combination as set forth in claim 2 wherein said nozzle means includes a plurality of skewed exit nozzles, control means for maintaining the direction of thrust of each of said skewed exit nozzles parallel to the axis of said vehicle.

6. A combination as set forth in claim 3 wherein the control means senses a change in ambient pressure.

7. A combination as set forth in claim 1 wherein means are provided for moving said skewed exit nozzle to maintain its direction of thrust parallel to the axis of said vehicle during changes in altitude.

8. A combination as set forth in claim 4 wherein four skewed exit nozzles are included all spaced equally about the axis of said vehicle, the inclined exit plane of each nozzle facing outwardly.