United States Patent [19]

Nay et al.

[11] **3,744,743**

[45] **July 10, 1973**

[54] **HELICOPTER POWER PLANT SYSTEM**

[75] Inventors: **Harvey O. Nay,** Palos Verdes Estates; **Frank S. Okamoto,** Torrance; **Robert E. Head,** Palos Verdes Estates; **Richard E. Moore,** Los Angeles; **John M. McDermott,** Torrance, all of Calif.

[73] Assignee: **Gates Learjet Corporation,** Wichita, Kans.

[22] Filed: **Sept. 11, 1970**

[21] Appl. No.: **71,319**

[52] **U.S. Cl.** **244/17.11,** 60/39.35, 244/6, 244/55, 416/170

[51] **Int. Cl.** **B64c 27/12**

[58] **Field of Search** .... 416/170; 60/39.35; 244/17.11–17.27, 6, 7, 6 R, 7 R, 7 C, 53 R, 54, 55

[56] **References Cited**

UNITED STATES PATENTS

2,755,038	7/1956	Gluhareff	416/170 X
2,911,851	10/1959	Wachs	416/170 X
2,947,497	8/1960	Sznycer	416/170 X
2,665,859	1/1954	Papadakos	244/7 R

FOREIGN PATENTS OR APPLICATIONS

1,115,450	4/1956	France	244/6

Primary Examiner—Milton Buchler
Assistant Examiner—Paul E. Sauberer
Attorney—Richard A. Marsen

[57] **ABSTRACT**

Two turbine engines power the craft. They are positioned at the main rotor hub region just above the cabin. Each engine extends laterally, cross-ship. A simplified transmission/gearing system results. Also, should one engine fail, the other readily takes over alone. A nacelle encloses each lateral engine, in the form of a stub wing. The nacelles are set at a positive incidence angle, and provide a substantial lift that unloads the main rotor and saves in the overall horsepower requirement. They are of relatively small down area, to minimize downloading due to rotor downwash. Their leading edge has an inlet slot for engine air. The exhaust ports are in their outboard edges to direct the noise and hot gases away from the craft. The wing-like nacelles are symmetricaly arrayed, and aerodynamically as well as esthetically integrated with the helicopter.

12 Claims, 6 Drawing Figures

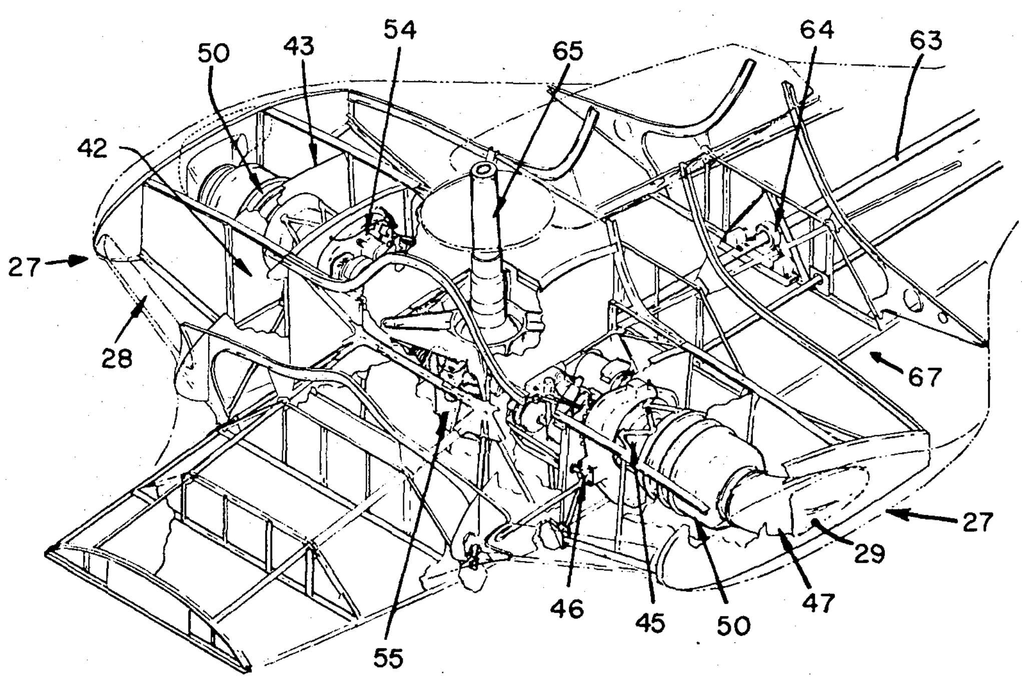


FIG. 1

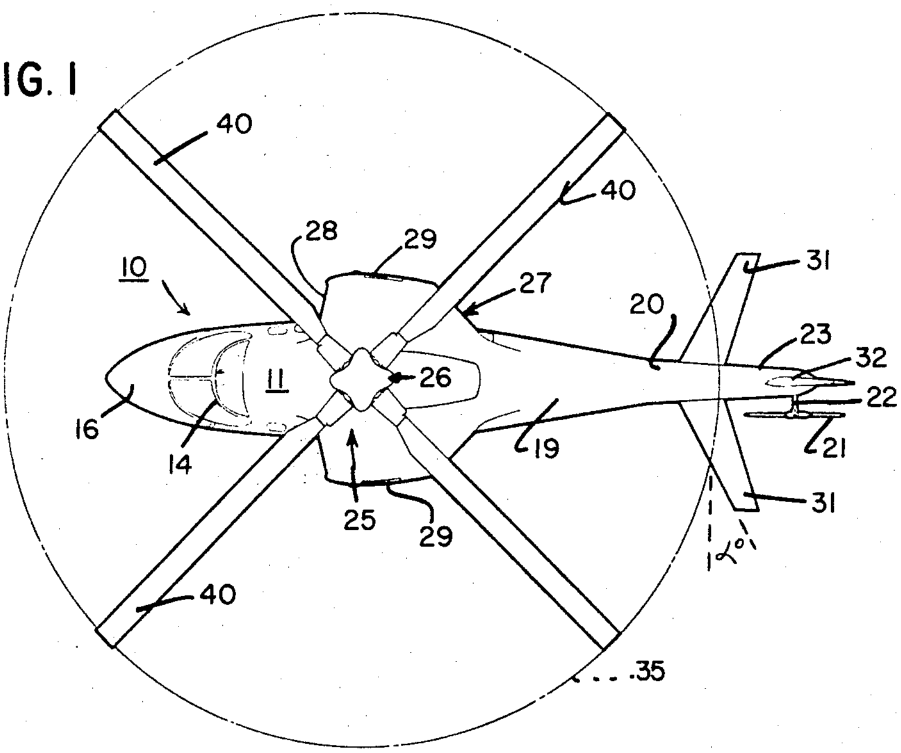
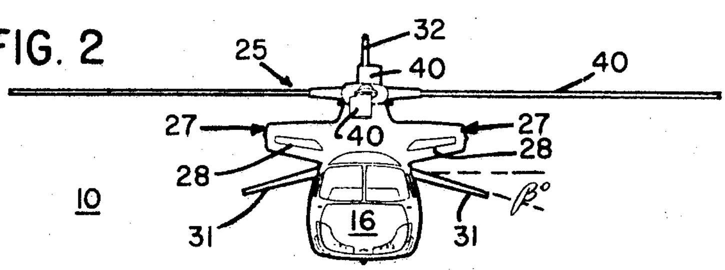


FIG. 2



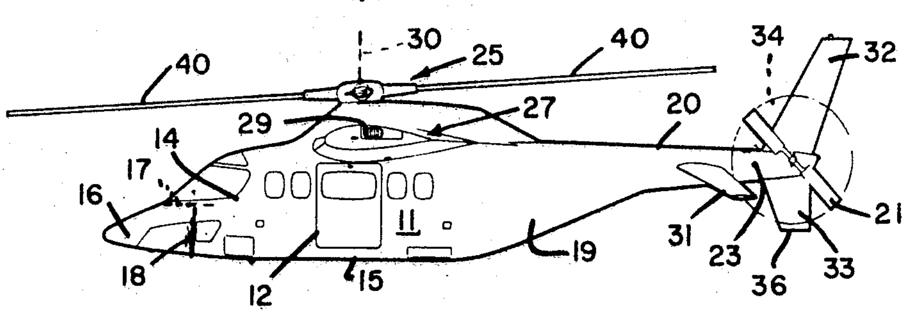


FIG. 3

INVENTORS:

Harvey O. Nay
Frank S. Okamoto
Robert E. Head
Richard E. Moore
John M. McDermott

By

Their Attorney

FIG. 4

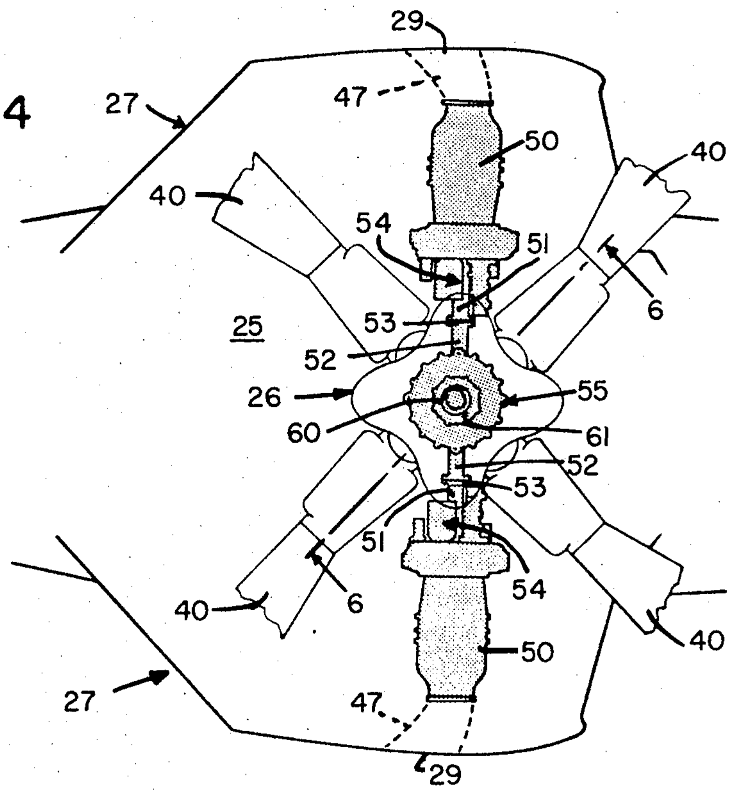
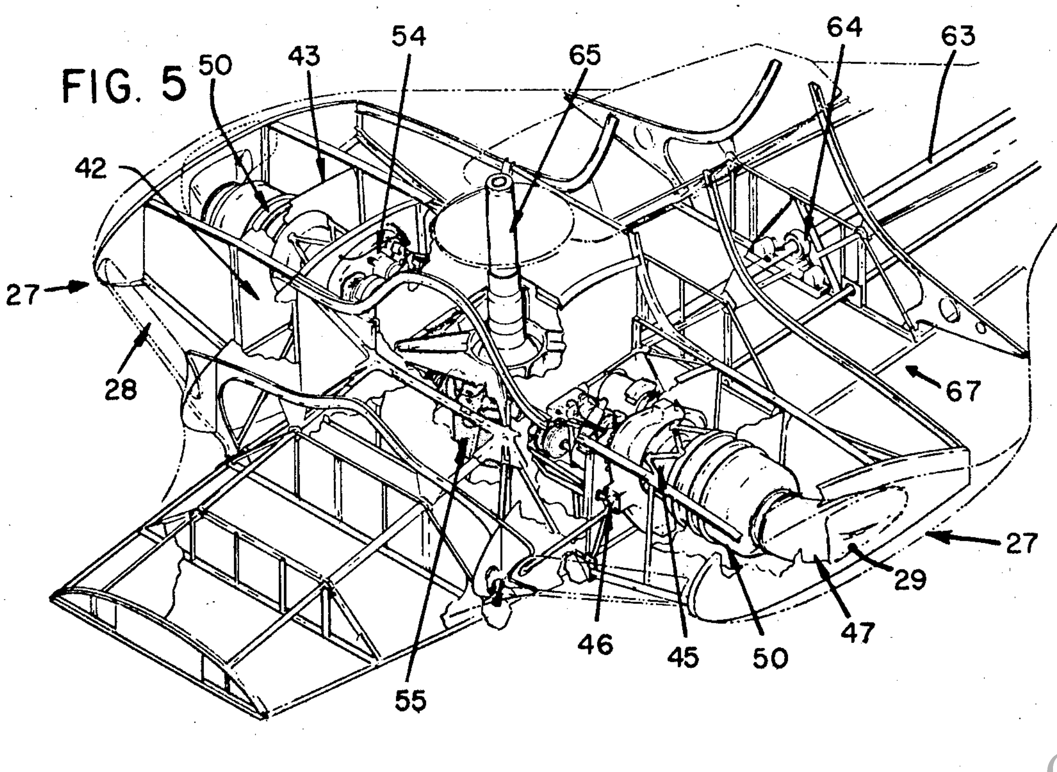

29
47
27
50
40
40
54
51
53
25
52
26
55
60
61
52
53
51
54
6
6
40
40
50
27
47
29

FIG. 5


50
43
54
65
64
63
42
27
28
67
55
46
45
50
47
29
27

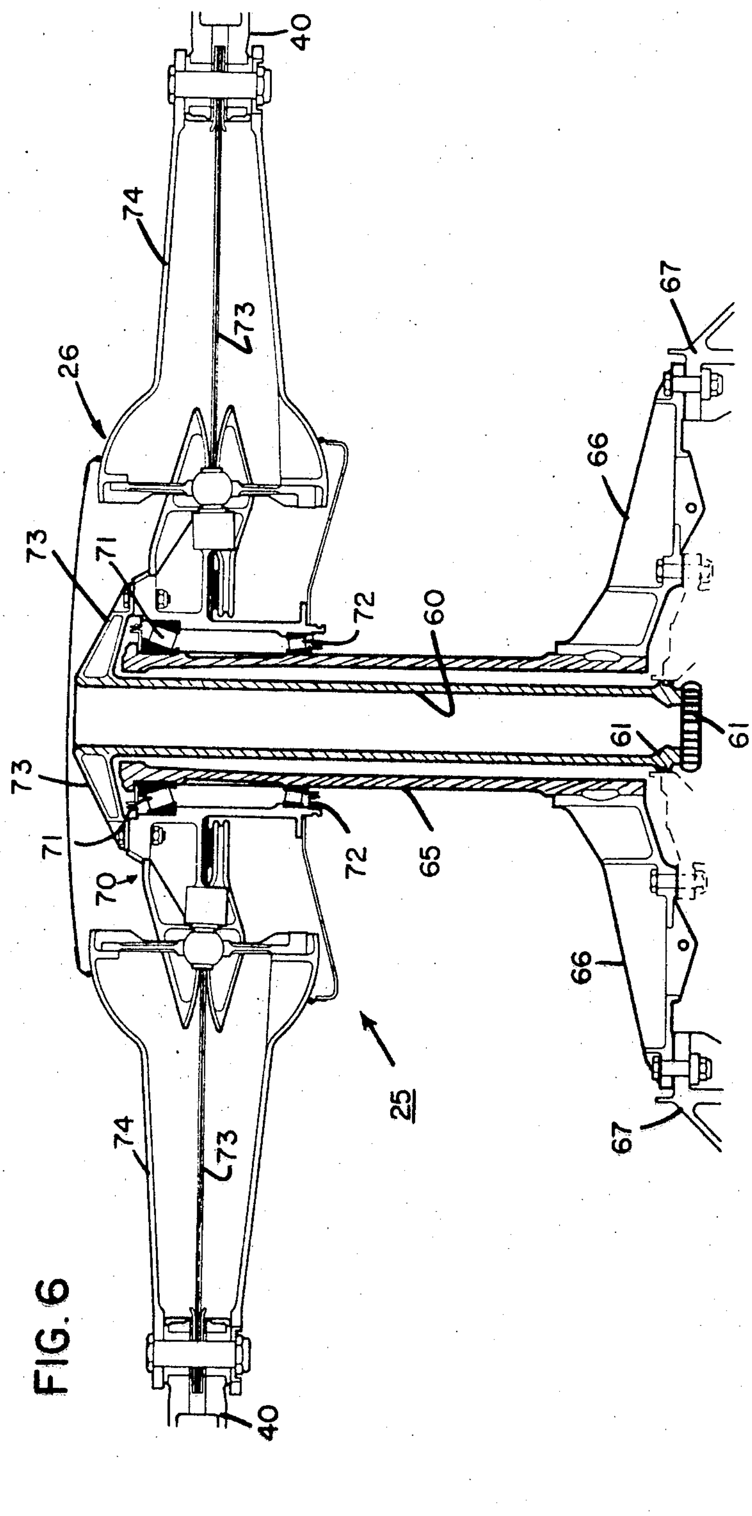


FIG. 6

HELICOPTER POWER PLANT SYSTEM

BACKGROUND AND SUMMARY OF THE INVENTION

The engine power plant for helicopters have heretofore been located for utility with little concern as to final appearance of the craft or their resultant drag. Further, the transmission from engines to main rotor shaft required gearing and mechanism that added cost and weight, and reduced reliability.

In accordance with the present invention, two engines are positioned laterally across the craft, at the main rotor hub level above the main cabin. They are directly coupled to the main rotor drive shaft through simple planetary gearing. Should one engine fail, the remaining one can safely power the helicopter. Each engine is enclosed in a fairing that extends only little beyond the engine. Air inlets for the engines are provided at the leading edges of the nacelles. The engine exhaust is directed outwardly through a port at the outer edge of its nacelle.

The nacelles are in effect stub-wings, with a minumum plan area to keep down thrust low due to the rotor downwash. They extend relatively little laterally for the same reason. Yet they streamline the engines with resultant low drag. Further, the nacelles, being winglike in form, and set at a positive incidence angle, provide significant lift. Their upward thrust unloads the rotor by the order of ten percent. Horsepower requirement is correspondingly reduced.

The turbine wheels are laterally positioned to spin in planes that do not intersect the body of the craft. This is an important safety factor should one disintegrate in flight. The engines readily disconnect from the main rotor transmission if stalled in flight. Thus one engine can take over, or if both disabled, autorotation may promptly proceed, smoothly to a safe landing at a site in a wide area of selection.

The helicopter hereof is aerodynamically and operationally efficient, fail-safe and stable. It is esthetically pleasing, which is advantageous for civilian design of the helicopter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of an exemplary helicopter incorporating the power plant system of the present invention.

FIG. 2 is a front elevational view of the helicopter of FIG. 1, with its main rotor blades turned 45°.

FIG. 3 is a side elevational view of the helicopter of FIGS. 1 and 2, with the main rotor blades oriented as in FIG. 2.

FIG. 4 is a schematic showing of the main rotor drive system including its two lateral engines.

FIG. 5 is a perspective view of the power plant and drive system for the main rotor blades, in position in the airframe.

FIG. 6 is an enlarged cross-sectional view through the main rotor support system at the hub, taken along the line 6—6 in FIG. 4.

DETAILED DESCRIPTION OF THE INVENTION

The exemplary helicopter **10** is designed with an overall configuration for civilian and executive travel use. Its airframe is formed with minimum fuselage drag for efficient high-speed cruise. Central cabin section **11** contains door **12** that opens close to bottom **15** of the fuselage so that the cabin floor is at a low level for easy entrance and exit. The cockpit area **14** at the front has a nose section **16** at its tip. Nose section **16** is arranged to be removable. It is detachable along its junction with cockpit **14** along the dash-lines **17, 18** to provide easy and direct access to the avionics, instruments, etc for servicing. Behind the main cabin area **11** is baggage compartment **19**, extending rearwardly to narrowed end-fuselage section **20**, to complete the helicopter body. A drive shaft **63** (FIG. **5**) extends through fuselage section **20** to couple the central main rotor drive with the tail rotor drive. A drive rod **22** projects from tip **23** of the fuselage (FIG. **1**) for the tail rotor, terminating in an interior take-off gear box (not shown). A tail rotor drive shaft connects this gear-box (not shown) to the main rotor drive, seen at **63** in FIG. **5**, through damper **64**.

The single main lifting rotor **25** has four elastically restrained blades **40,40** assembled 90°apart. Rotor blades **40, 40** are arranged with significant flap hinge offset for good flying qualities with low vibration levels. A static mast structure is attached directly to the body of the helicopter, as described hereinafter in connection with FIG. **6**. The rotor hub is mounted thereon by suitable bearings for its rotation. Equivalent main rotors, per se, may instead be used insofar as the present invention is concerned.

The rotor blades **40, 40** are coupled at central hub **26**. The main rotor **25** and the tail rotor **21** are driven by laterally disposed turbine engines **50, 50** within respective wing-like low-drag nacelles **27, 27**. Each engine nacelle **27** contains an air inlet slot **28** at its leading edge that directs air to the contained engine (**50**), and an outboard exhaust port **29**.

In accordance with the present invention, the fairings **27,27** are arranged to provide sufficient lift in cruise flight to more than make up for their drag. They are symmetrical, cross-ship, and exhibit minimum aerodynamic interference with rotor **25**. There is negligible download on them in flight because of their relatively small span. In the exemplary helicopter: The main rotor drive shaft is tilted 4° forwardly from vertical (**30**), see FIG. **3**. The incidence of the winglike fairings **27, 27** hereof is 6°. The horizontal tail **31, 31** is arranged at an incidence angle relative to the engine fairings **27, 27** and the rotor angle, to optimize lift and moment factors. Wind tunnel tests have shown that minus-two-degree incidence for tail sections **31, 31** provides these factors with optimum result and minimum interference.

The tail rotor **21** is a straight forward two-blade type, mounted on a teetering hinge. It is located laterally of fuselage tip **23** through its drive rod **22**. Its rotor blades are closely behind horizontal tail surfaces **31, 31** yet positioned to avoid mechanical interference therewith. The vertical tail is composed of an upper segment **32**, and a lower one **33**. Vertical tail areas **32, 33** are sufficiently sized to make the helicopter directionally stable, even in the extremely unlikely event of loss of the tail rotor (**21**) and/or failure of the tail rotor drive system. Vertical tail surfaces **32, 33** are cambered, and set an an incidence angle to significantly unload tail rotor **21** in cruise flight, minimize tail rotor fatigue loads and maximize tail rotor life.

Lower section **33** oF the vertical tail is used as a protective bumper to keep tail rotor **21** from contacting ground in a tail low landing, as noted in FIG. **3**. The circular tip path of the tail rotor is indicated by lines **4**.

The lowest edge 36 of tail section 33 is below tip circle 34. The surface areas of vertical tail sections 32, 33 serve as a safety barrier against approach to the tail rotor (21) from the opposite side. This factor, combined with the proximity of swept-back horizontal tail wings 31, 31 form a significant safety zone about the tail rotor 21 when the helicopter is on the ground.

Horizontal tail wing-sections 21, 21 extend symetrically from the narrow rear portion 20 of the fuselage, as seen in FIG. 1. The tail sections 31, 31 each are oriented rearwardly, by $\alpha°$. The disc area under rotating main rotor 25 is indicated by dash-line circle 35. As seen in FIG. 1, a disc area 35 intersects radially interior portions of tail wings 31, 31 where the downloading effect is minimal. The download due to downwash in hovering is a negligible factor with the exemplary horizontal tail 31, 31. The sweptback extent of its wing sections 31, 31 fall effectively beyond the downwash within disc area 35 (in hover). The increasing radial portions of the horizontal wings extend beyond this downwash. In addition to said swept-back configuration, the two tail wings 31, 31 are also arranged with a downward sweep, as best seen in FIG. 2. Their downward sweep is at a substantial anhedral angle $\beta°$, being a negative dihedral angle. The symmetrical rearwardly extending and downwardly projecting horizontal tail wings 31, 31 provide smooth transition from hover to forward flight, since the downwash of rotor blades 40, 40 recedes backwardly across the horizontal tail during the transition. Further details thereof are set forth in our concurrently filed patent application Ser. No. 71,320, filed on Sept. 11, 1970, now abandoned for "Helicopter Tail Configuration."

Turbine engines 50, 50 are incorporated to directly couple to the central transmission/gearing 55. The engines 50, 50 extend radially outwardly from the transmission 55. In the preferred embodiment hereof, the turbine engines 50 are positioned laterally, cross-ship, as shown in the drawings. As can best be seen from FIGS. 2 and 3, the extension of the axes of the turbine engines 50 are horizontally offset from the main axis of the fuselage. The drive shaft 60 for the main rotor assembly 25 is directly mechanically connected to the center of the transmission/gearing system 55. Drive shaft 60 is made hollow to save weight. Its driven gear 61 is secured at its internal end 62, see FIG. 6. The engine power output drive shafts 51—51 are short, and connect into shafts 52, 52 of the power transmission 55 through flexible end-couplings 53, 53, see FIG. 4. The internal gearing of the transmission 55 hereof is simple, direct, effective and efficient, with a minimum number of parts. It is significantly less in weight and cost, and with improved reliability when compared with prior art systems.

A preferred transmission/gearing 55 is a planetary array between its coupling shafts 52, 52 and the central rotor gear 61. In its main gearbox 55 engines 50,50 each drive a pinion through an overrunning clutch. These two pinions in turn drive a single ring gear that serves as the input to the planetary second stage. The main rotor shaft 60 transmits only torque to rotor 25. All other rotor loads are carried through stationary rotor mast 65. Cooling air is provided for engine 50 and main rotor gearbox 55 by an engine-driven fan mounted with the accessories 54 of each engine. Air from each of said fans is distributed to the engine oil cooler for that engine, to the engine's accessory compartment, and to one-half of the oil cooler for rotor gearbox 55. The latter assures adequate gearbox 55 cooling even when one engine is inoperative. Discharge air from the engine oil cooler is directed to ventilate the compartment about the hot end of the engine.

The laterally-disposed position of the turbine engines 50, left-and-right, gives good separation and redundancy to prevent any disaster that may occur to one engine from spreading to the other engine. The turbine wheels of each engine 50, 50 are located well outboard of the fuselage, including the cabin section 11 and cockpit 14. Said wheels spin in a plane that does not intersect the fuselage. Thus in the unlikely event of a turbine wheel disintegrating, and not being contained by the engine case, it could not endanger the crew or passengers nor damage the hull at all. The exhaust port 29 of each engine 50 is placed well outboard where its heat and noise have minimum influence on passenger comfort.

The lateral position of the engines 50, 50 allows the use of a wing-like, low-drag fairing 27, 27 to enclose each engine. The fairings 27, 27 supply enough lift in cruise flight to more than make up for their drag. This feature is made possible by optimizing the incidence angles of the engine fairings 27, 27, the rotor 25, and the horizontal tail 31, 31 as aforesaid. Each nacelle exhibits minimum aerodynamic interference with the rotor 25, and has negligible download in hover because of its relatively small span. A slotted inlet 28, along the leading edge of each fairing 27 directs the inlet air into an efficient inlet plenum-chamber 42 for each engine 50, see FIG. 5. A firewall 43 forms one wall of chamber 42. The inlet sections 45, 45 of the engines are in chambers 42, 42. An engine forward mount is indicated at 46. The engine exhaust conducts 47, 47 extend to the respective outport exhaust ports 29, 29.

The exemplary helicopter 10 is a twin-turbine 50, 50 power system. Either disabled turbine 50 may be arranged to be promptly disconnected from the power drive system. This is done with the use of automatically disconnectable couplings at 53, 53 between turbines 50, 50 and main gear box 55; overrunning clutch couplings; or other known de-clutching means. It is an important back-up fail-safe factor in that the remaining engine can safely power the craft. Also, if a turbine break would not unduly load the transmission 55 its disconnection is optional. Single-engine performance of the exemplary helicopter is readily designed to exceed FAR 29 Category A helicopter requirements.

The main rotor hub 70 is mounted on stationary tubular mast 65 by support bearings 71, 72, see FIGS. 5 and 6. Hollow mast 65 is attached to mast base 66, which in turn is directly secured to the airframe structure 67. This provides main rotor 25 support independent of the drive system. No once per revolution fatigue loads are thereby imposed on the static mast. Drive system failure, even lockup of a gearbox, can be sustained and still allow a safe autorotational landing. Rotor hub 70 is connected with drive torque shaft 60 by overhanging members 73, 73, and is coaxial within mast 65 much in the manner of a "full floating" truck wheel. In such way all forces and bending moments are carried by the stationary mast 65.

All the bearings in the main rotor hub 70 are designed for zero maintenance. The two grease-packed main rotor bearings 71, 72 go without attention between major overhauls. The blade 40 flap/feather, leadlag, and control link bearings are teflon-lined and need no lubrication. The blades **40, 40** are attached to the rotor hub **70** by laminated retention straps **73, 73** made of thin, high-strength steel. The straps **73, 73** transfer the blade centrifugal forces between the two blades in each opposing pair of the four-bladed rotor **25**; and deliver the engine torque to the blades (**40,40**) through their truss shape. Straps **73, 73** also withstand the alternating flapping, feathering, and chordwise loads applied by the blades **40, 40**, while still being flexible enough to allow the necessary flapping and feathering motions of the blades. Such design eliminates the need for the highly loaded, not fully rotating ball bearings that retain the blades in some prior helicopters, and so eliminates the brinelling problem associated with that type of blade retention. The rotor hub is covered with fairings **74, 74** to minimize aerodynamic drag, and also to protect its mechanism from dust and dirt, and from icing.

As a final safety backup the helicopter **10** has outstanding autorotational characteristics. Therefore, even with a highly improbable dual engine failure or running out of fuel, a safe power-off landing can be made almost any place with the helicopter. Its exceptionally low aerodynamic drag also provides a long glide capability. Thus, for example, for an autorotation from 5,000 feet, nearly 100 square miles of area are available for choosing an emergency landing site.

The engine nacelles **27, 27** are aerodynamically shaped to produce lift with low drag, as herein-above set forth. They are smooth fairing enclosures for the respective laterally positioned engines **50, 50.** Their incidence angle is carefully determined in conjunction with that for the horizontal tail **31, 31** and the forward inclination of the main rotor drive. In the exemplary craft with a forward 4° tilt of the main rotor, the incidence of these "stub wings" **27, 27** was set at 6°, positive. They help unload the rotor **25** by providing vertical thrust. The nacelles **27, 27** may be said to in effect "pay for themselves" in unloading the projecting engines. For example, the helicopter **10** with a gross weight of 6,000 pounds uses shaft horsepower of 600 at 175 m.p.h., at an altitude of 5,000 feet. The nacelles **27, 27** at 6° incidence provides 10 percent of the rotor lift, or 600 pounds. A 5 percent saving in engine power results, namely 30 HP. Other nacelle incidence angles may be used. Increasing it further may decrease rotor output power.

It is advantageous to limit the lateral extent of nacelles **27, 27,** as well as hold their plan area to a practical minimum. The reason is to thereby reduce the downloading action of the main rotor downwash upon them: the less their plan area and lateral projection, the less the download. Practical turbine engines **50, 50** for the required power are available with reasonable shaft length, and good power to weight ratio. The Garrett TSE 231 helicopter turboshaft engine weighs about 175 pounds, yet develops 475 shaft horsepower for takeoff under sea level static conditions; with a continuous maximum of 400 shaft HP. Its power-to-weight ratio is 2.73.

The exemplary helicopter's cabin, arranged to seat 8–12 passengers, has an outer width of 5 feet. Its gross weight is designed at 6,000 lbs. The tip-to-tip, cross-ship, extent of nacelles **27, 27** is only 11 feet. The main rotor diameter is 40 feet; overall height to top of vertical tail, 12 feet; height at main rotor hub, 10 feet. The cross-ship extent of the horizontal tail wings **31, 31** is about 14 feet. The height of the upper tail section **32** extends to 12 feet above the cabin floor-line; its lower section **33** at bottom **36** to about 2 feet above. The tail rotor diameter is about 7 feet, and is positioned 21 inches outwardly from the craft 's central longitudinal section.

The exemplary "stub wings" **27, 27** each extend laterally from the top of the cabin **11** by 3 feet. They taper, narrowing outwardly: being 9 feet longitudinally at their cabin junctures, and 5.75 feet along their outboard edge. They are streamlined to minimize drag and provide the lift, as aforesaid; see FIGS. **1, 2** and **3.** They are nacelles that enclose the turbine engines **50** in lateral position across the craft.

It is to be understood that the fairings **27, 27** may be of other form, shape and/or size, and remain within the purview of our present invention. Essentially, they are constructed: (a) to materially reduce the drag of the engines **50** that would otherwise be exposed over the cabin; (b) streamlined in form and set at a positive incidence angle to provide substantial added lift to the helicopter, even beyond that of the weight of their engines **50**, and thereby help unload the main rotor; (c) with relatively low down area and short lateral projection to minimize downloading due to main rotor action; and (d) aerodynamically integrated with the forward rotor inclination, the horizontal tail incidence and the fuselage as a whole for efficient, stable operation of the craft.

Fairings **27, 27** are not wings in the sense of those used in fixed wing aircraft. They have a relatively small span, and provide a relatively small proportion of the overall requisite lift; herein the order of ten percent. Were these "stub wings" extended laterally outwardly, the resultant down thrust would correspondingly increase greatly, until a span is reached where their utility becomes negative. The relatively short engines **50, 50** with the laterally short nacelles **27, 27**, as three feet, set at plus 6° incidence, have been found to be effective, stable and very useful for the helicopter.

We claim:

1. A helicopter comprising:

a fuselage;

a main rotor rotatably mounted over the fuselage;

a drive shaft for the main rotor;

two turbine engines supported on the fuselage with their longitudinal axes extending generally laterally from and substantially perpendicular to the longitudinal axis of the fuselage, the main axis of which is horizontally offset with the extension of the axes of the turbine engines and the longitudinal axis of each of the engines being substantially parallel to each other; and

transmission means coupling the power output shafts of both engines with said drive shaft to power said rotor.

2. A helicopter according to claim **1,** further including a nacelle about each engine formed to provide relatively low drag and an upward lift to the helicopter.

3. A helicopter according to claim **2,** in which said nacelles are arranged at a positive incidence angle to provide significant upward lift in flight.

4. A helicopter according to claim **2,** in which each nacelle has an air inlet for the contained engine, and an exhaust port therefor at a separate location.

5. A helicopter comprising:

a fuselage;

a main rotor rototably mounted over the fuselage;

a drive shaft for the main rotor;

turbine engines supported on the fuselage with the longitudinal axes of the engines extending generally from said fuselage and substantially perpendicular to the longitudinal axis of the fuselage and the longitudinal axis of each of the engines being substantially parallel to each other,

said turbine engines having turbine wheels positioned to spin in planes that do not intersect said fuselage; and

transmission means coupling the power output shafts of said engines with said drive shaft to power said rotor.

6. A helicopter according to claim **5,** in which said transmission means is planetary gearing, a driven gear connected with said rotor drive shaft, said driven gear being coupled centrally with said planetary gearing.

7. A helicopter according to claim **6,** further including a coupling unit between each said engine output shaft and said planetary gearing.

8. A helicopter according to claim **7,** in which each said engine when disabled is readily disconnected from said planetary gearing across its said coupling, and thereby permit the remaining engine to power the helicopter.

9. A helicopter comrpising:

a fuselage;

a main rotor rotatably mounted over the fuselage;

a drive shaft for the main rotor;

turbine engines supported on the fuselage with their longitudinal axes extending laterally from the fuselage and substantially perpendicular to the longitudinal axis of the fuselage and the longitudinal axes of the engines being substantially parallel to each other;

nacelles laterally extending from each side of the fu-

selage encompassing the engines,

said nacelles formed to provide relatively low drag and an upward lift to the helicopter, and

said nacelles further having a wing-like shape and extending outboard little beyond the encompassed engines whereby low download effects due to rotor downwash are exerted thereon; and

transmission means coupling the power output shafts of both engines with said drive shaft to power said rotor.

10. A helicopter according to claim **9,** in which said nacelles are arranged at a positive incidence angle to provide significant upward lift in flight.

11. A helicopter according to claim **9,** in which the leading edge of each said nacelle has an air inlet for the contained engine, and the outboard edge thereof provides an exhaust port therefor.

12. A helicopter comprising:

a fuselage;

a main rotor rotatably mounted over the fuelage;

a drive shaft for the main rotor;

engines supported on the fuselage with their longitudinal axes extending laterally thereof;

nacelles about each engine formed to provide relatively low drag and an upward lift to the helicopter,

said nacelles having a wing-like shape and extend outboard little beyond their respective engines, whereby low download effects due to rotor downwash are exerted thereon,

and further in which the nacelles and their engines therein are positioned near the top region of the central cabin section and extend to the main rotor hub; and

transmission means coupling the power output shafts of both engines with said drive shaft to power said rotor.

* * * * *