Dec. 9, 1969 B. LINDENBAUM 3,482,803

HEAVY LIFT HELICOPTER

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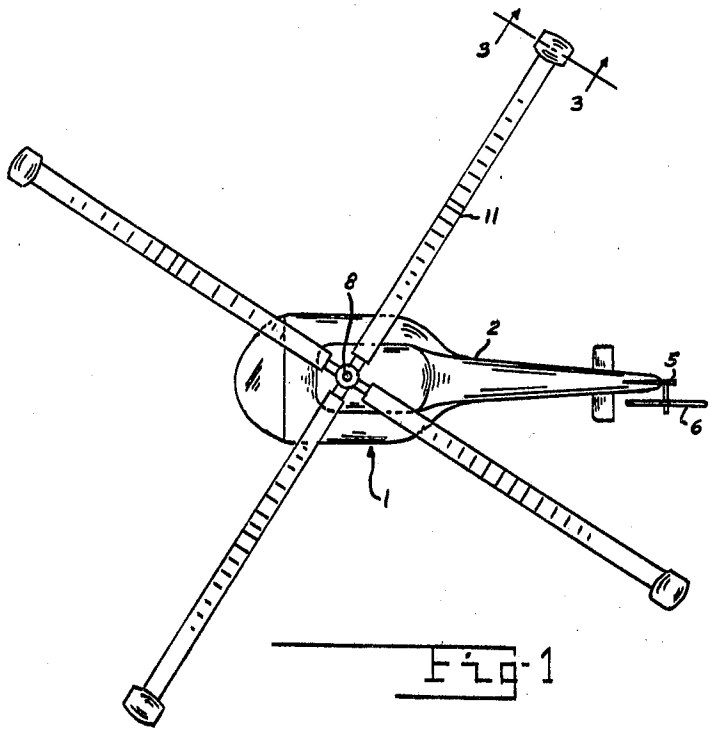


Fig-1

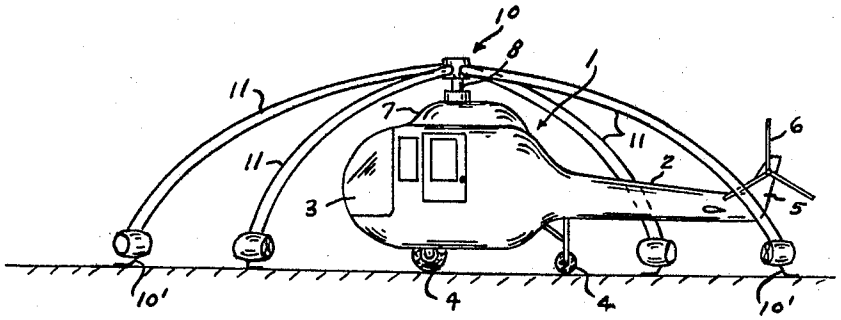


Fig-2

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HEAVY LIFT HELICOPTER

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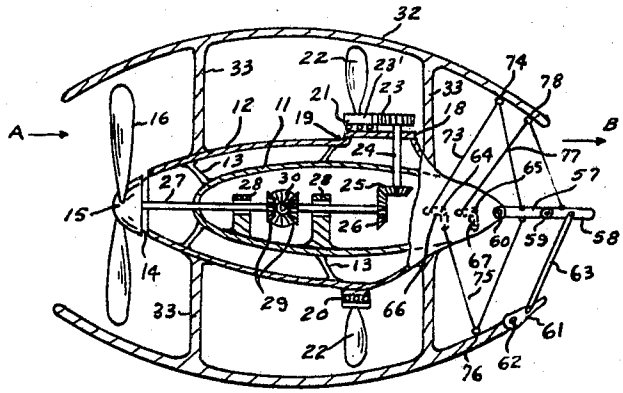


Fig. 3

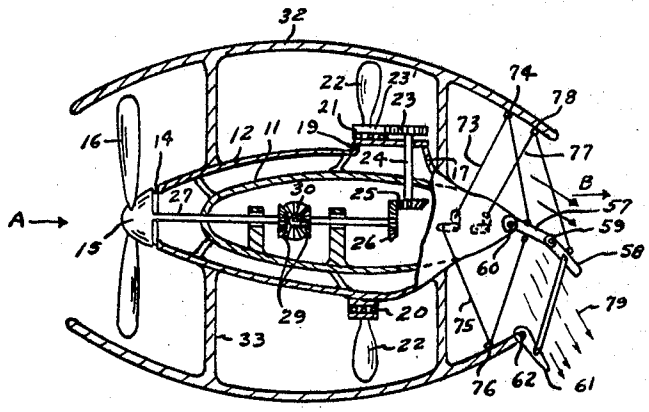


Fig. 4

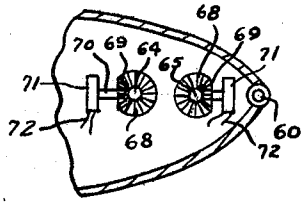


Fig. 5

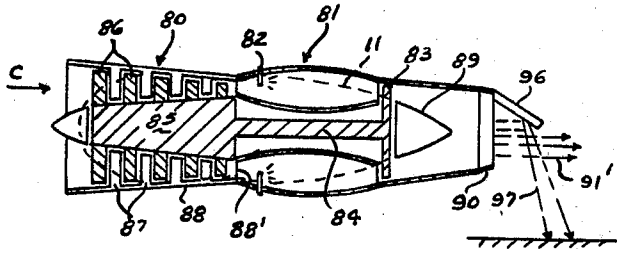


Fig. 7

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HEAVY LIFT HELICOPTER

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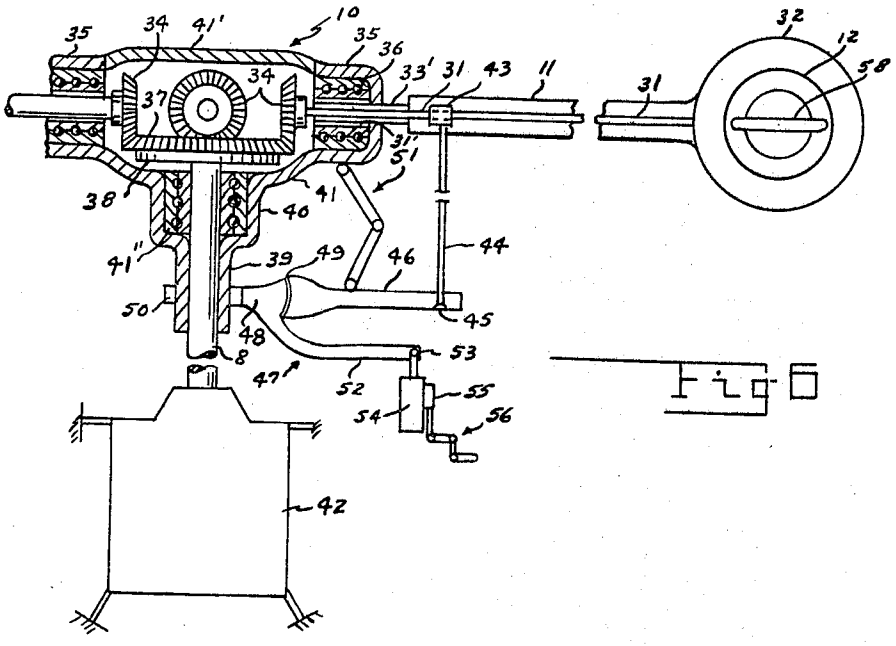


Fig. 6

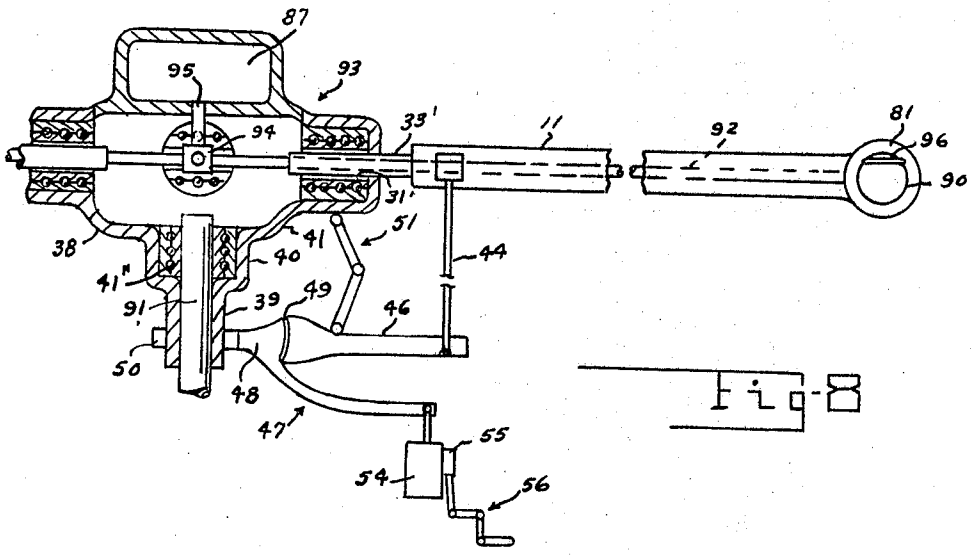


Fig. 8

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Dec. 9, 1969 B. LINDENBAUM 3,482,803

HEAVY LIFT HELICOPTER

Filed April 25, 1968 6 Sheets-Sheet 4

Fig-9

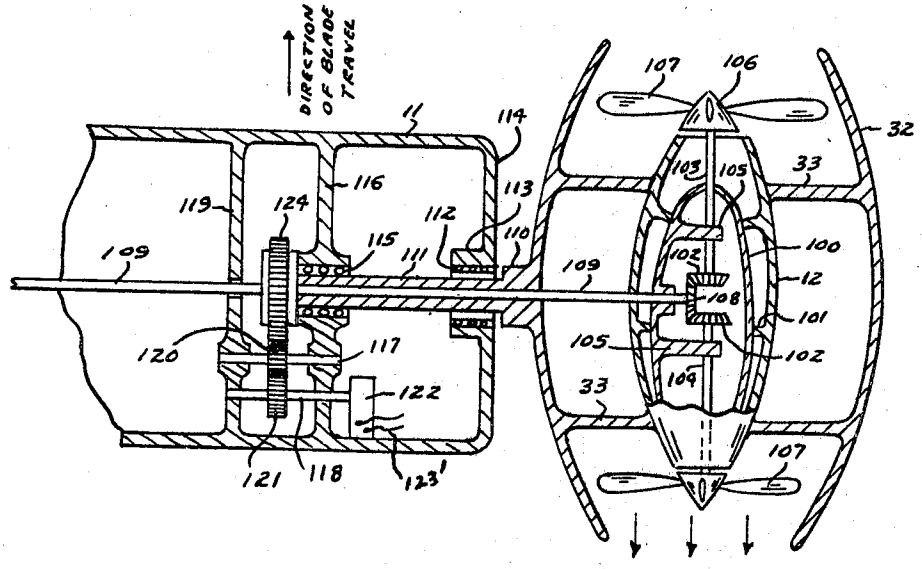
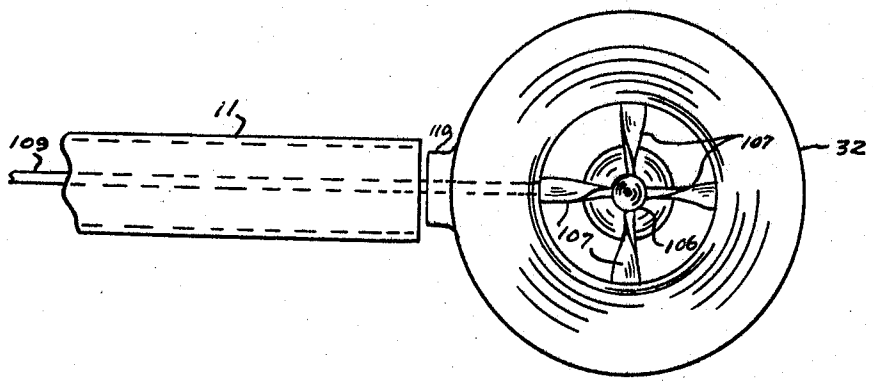


Fig-10



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Dec. 9, 1969 B. LINDENBAUM 3,482,803

HEAVY LIFT HELICOPTER

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Fig-11

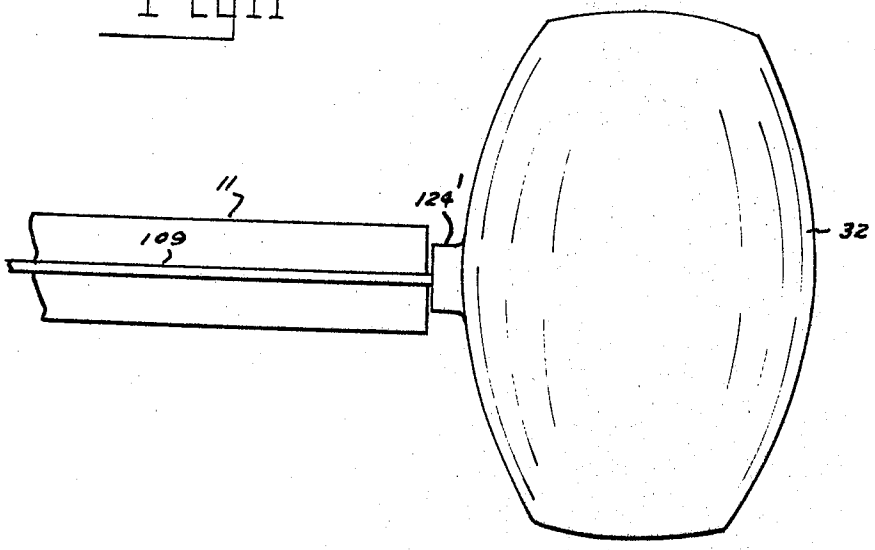
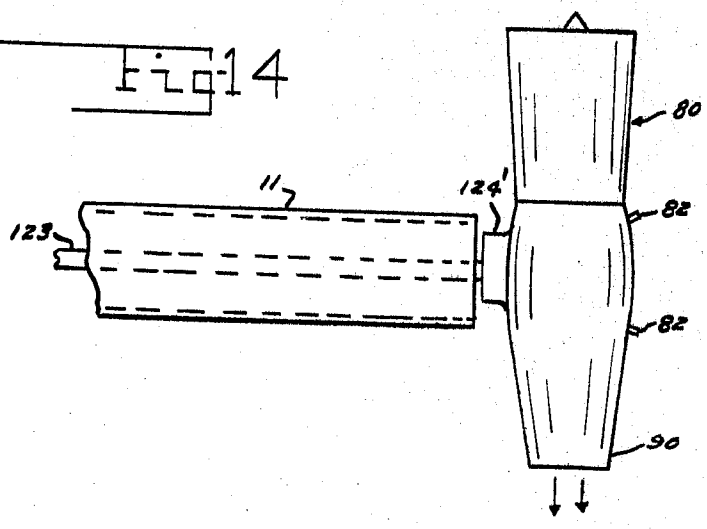


Fig-14



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HEAVY LIFT HELICOPTER

Filed April 25, 1968 6 Sheets-Sheet 6

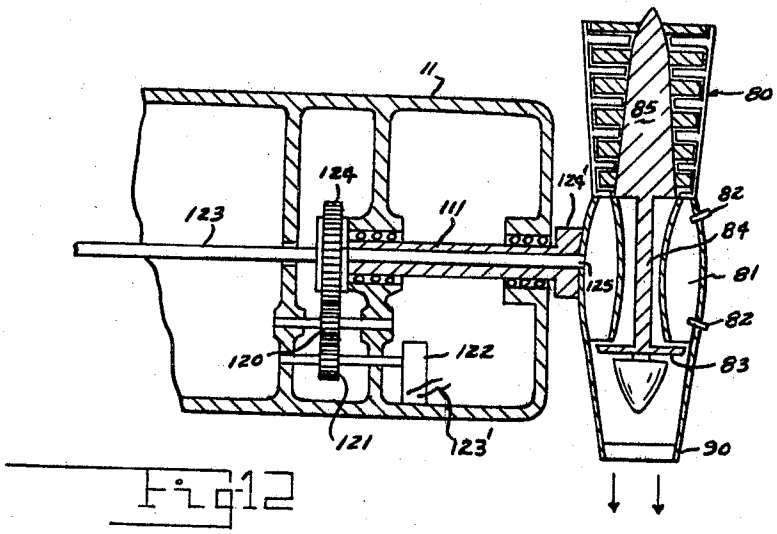


Fig-12

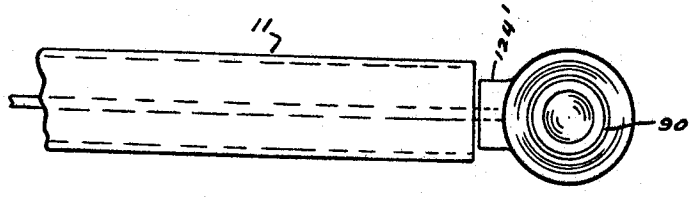


Fig-13

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3,482,803

HEAVY LIFT HELICOPTER

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Int. Cl. B64c 27/18
U.S. Cl. 244—17.11 9 Claims

ABSTRACT OF THE DISCLOSURE

A heavy lift helicopter in which the rotor diameter is sufficiently large or the "disc loading" and "solidity" are so low as to cause the blades actually to droop to the ground when in a static position. A reaction drive system which may constitute propellers, shrouded fans, turbojets or turborfans is mounted on the blades toward their outboard extremities to direct a fluid stream toward the ground. The fluid stream is directed by tabs under control of the pilot, and the tips of the blades are lifted out of contact with the ground in order to leave the blades free to turn. The same drive system is then employed to rotate the blades to cause the helicopter to fly.

The reaction drive system may also comprise a propeller structure, a jet device or a turbofan, swivelly mounted at the end of each blade but physically separate from the blade. The turning of these members is controlled by the pilot and each member directs a flow of air or gas toward the ground to elevate the blade tips with respect to any obstruction.

BACKGROUND OF THE INVENTION

In the design of helicopter rotors, low disc loading is a desirable feature from the standpoint of lifting high load for a given horsepower, reduction of external noise and downwash disturbance. In such rotors the low disc loading is achieved by increasing the rotor diameter, without change in the blade area, so that the solidity ratio (blade area to disc area) is decreased. The blades become long and the chord and thickness become proportionately less in respect to this length leading to increased flexibility flapwise and chordwise (perpendicular and in the plane of rotation respectively) and torsionally. When the rotor diameter is sufficiently large or the disc loading and solidity are sufficiently low, the blades may actually droop to the ground unless the rotor hub is located sufficiently high above the ground.

SUMMARY OF THE INVENTION

The problem of droop of such rotor systems is solved by the use of a reaction drive system mounted on the blades toward the outboard extremities, and the thrust produced thereby is vectorable to produce a vertical force and thus to raise the blade tips. The reaction or thrust producing systems may be in the form of engine-driven propellers, shrouded fans, turbofans or turbojets. The engines which provide the power can be mounted either on the fuselage, inboard on the blade or hub, or directly with the thrust producer. By controlling the vertical and tangential blade drive forces prior to rotation, the blade may be raised vertically to an operating position so that the blade rotation can commence safely, or alternately lowered to the ground upon cessation of rotation. Once in rotation, the normal blade lift and centrifugal force act to keep each blade in proper extended attitude.

Reference will now be made to the drawings which show several embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 represents a plan view of a helicopter employing four blades as representative of a multiblade machine, and

provided with blade tip lifting accouterments in accordance with my invention;

FIG. 2 is an elevational view of a heavy lift helicopter and showing the extremities of the rotor as being in contact with the ground;

FIG. 3 is a section, considerably enlarged, and taken along line 3—3 in FIG. 1, looking in the direction of the arrows;

FIG. 4 is a view similar to FIG. 3 but showing the structure by which an air flow is directed toward the ground;

FIG. 5 represents a fragmentary detailed view of the rear edge of a blade and showing the manner in which angular motion can be communicated to the flow deflecting mechanism;

FIG. 6 is a diagrammatic view, partly in section, of an engine drive and connecting shafts for causing the blade tips to elevate;

FIG. 7 represents a modified form of power unit for effecting the blade lift;

FIG. 8 is a diagrammatic view, partly in section, of a single blade assembly using the power unit shown in FIG. 7;

FIG. 9 is a fragmentary cross-sectional view of a modified form of the improved structure, looking toward the wide side of the blade, and showing a swivelable thrust producer which can provide a tip raising flow of air;

FIG. 10 shows an elevational view of the structure shown in FIG. 9;

FIG. 11 is a view of the structure shown in FIG. 9, partly in section and looking in the direction of the edge of the blade. The thrust producer shown in section has been rotated 90° from the position of FIG. 9;

FIG. 12 represents a fragmentary cross-sectional view of another modified form of the improved structure, looking toward the wide side of the blade and showing a swivelable thrust producer of the jet type;

FIG. 13 is an elevational view of the structure shown in FIG. 12; and

FIG. 14 is a view of the structure shown in FIG. 12, partly in section, and looking in the direction of the edge of the blade. The jet thrust producer has been rotated 90° from the position of FIG. 12.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1 there is shown a four-bladed helicopter to which my invention can be applied. Reference character **1** generally designates the body or cockpit of the machine provided with the usual fuselage **2**, outside doors and front viewing windows **3**. The helicopter is mounted on wheels **4**, tripod fashion, and the rear end fuselage carries a stabilizer tail **5** which may or may not, depending upon its aeronautical design, include a rudder (not shown). A tail rotor **6** can be mounted on the tail piece. The upper part of the body **1** has a pylon **7** which is provided with heavy duty bearings for a shaft **8**. It may be connected to an engine in a separate compartment of the fuselage. The shaft carries a housing or rotor hub generally indicated at **10** mounted thereon. The housing contains gearing driven by the shaft for causing the blades to turn in unison, together with the housing, as will be explained hereinafter. These blades, indicated at **11**, are quite long, some measuring 100 feet or more as in the case of a so-called "crane" or heavy lift helicopter exhibiting huge lifting power. It is desirable to keep the "disc loading" as low as possible in order to maintain this high lift capability for a given horsepower, also to minimize the external noise and reduce downwash disturbance. The low disc loading is achieved by increasing the rotor diameter without change in the blade area. Thus, as the length of the blade becomes greater to provide the enormous lift, the width of the blades becomes smaller. This consideration tends to slenderize

the blade both in width and thickness so that it becomes subject to a pronounced drooping effect in spite of the usual reinforcement within the blade and contained shafting and piping as explained hereinafter.

FIG. 2 illustrates this effect by showing the extremities of all four blades in contact with the ground through retractable skids **10'** although it will be understood that on occasion, as when the ground is uneven, perhaps only one skid or its blade would actually contact the ground. It would be difficult, if not impossible, to turn the rotor under these circumstances, even though the end of the blade can withstand considerable twisting effect. Accordingly, the primary object of the invention is to elevate either one or all the blades as may be necessary to free them or their skids from any contact with the ground before the rotor has started to turn.

In order to effect this purpose, I provide at the ends of each blade not only a propelling mechanism which serves the purpose of rotating the blades in unison about the shaft **8** but also is used as a vertical lifting means which provides a strong downdraft of air, projected toward the ground with sufficient force as to free the blade or blades of any contact with the ground.

Referring to FIGS. 3 and 4, there is provided about each blade **11**, a nacelle **12** constituted of relatively thin metal and taking the general form of the blade but held in spaced position from the latter by means of struts **13**. At the forward end of the nacelle a bearing member indicated at **14** is provided, terminating in a cone-shaped member **15**, and holding in position a fan or propeller **16** of any suitable and well-known type. This latter is adapted to rotate in a vertical direction in front of the nacelle. At the opposite end of the latter there is a protuberance indicated at **17** provided with a cap member **18** and having an opening therethrough. This member, to the left as seen in FIGS. 3 and 4, merges into an annular ring-like protuberance **19** which extends circumferentially about the nacelle and is carried thereby. The annular ring, at its perimeter is provided with a circular set of bearings **20** on which a circular base **21** of a fan or propeller **22** is mounted. The latter is thus adapted to rotate freely about the exterior surface of the nacelle. The base **21** is of sufficient thickness, in the radial direction as to carry gear teeth which extend peripherally about its edge surface and constitutes a ring gear. A gear is mounted in the cap member **18** and meshes with the teeth of the base member. As the ring gear **23'** is rotated in the manner described hereinafter, the propeller **22** is caused to rotate on its ball bearings. A shaft **24** connects the gear **23** with a beveled gear **25**, the latter being located within the body of the nacelle. The beveled gear meshes with a bevel gear **26** carried by a shaft **27**. The latter is journalled within the uprights **28** secured to the inner surface of the blade. The shaft **27** continues through the journal, and is connected to the hub member **15** of the propeller **16**. Thus, as the shaft **27** is rotated in a manner described hereinafter, the propeller **16** is caused to rotate; power is also supplied through the bevel gears **26**, **25** and the gear **23** to the base **21** of the propeller **22**. Thus, both propellers are caused to turn and the gearing is such that they will turn in opposite directions. By rotating the blades in opposite directions, the gyroscopic effect due to rotor rotation can be considerably reduced or eliminated. The shaft **27** is broken at the middle between the uprights **28**, and the ends terminate in bevel gears **29** which are driven by a relatively large bevel gear **30** mounted on a shaft **31**. In order to confine the air driven by the fans or propellers and provide aerodynamic benefits in performance, a circumferentially complete barrel-like shell or shroud **32** of metal or other suitable material is caused to surround the nacelle **12**. This shell is supported by a number of struts **33** extending radially outwardly from the nacelle **12** and is of such size as to allow clearance for the propellers **16**, **22**. The length of the shell extends to positions well in front of the propeller **16** and to the rear of propeller **22**. Thus, the air

flowing in a direction indicated by the arrow A is given tremendous velocity in passing between the nacelle **12** and the shell **32**, and leaves the latter in the direction indicated by the arrow B.

The blade **11** (FIGURE 6) is provided at the inner end with a blade shank **33'** which extends through a side opening in a large forging forming the hub **10**. The blade shank accommodates the shaft **31** which also enters the forging from the side and terminates in a bevel gear **34**. There is a bearing (not shown) located inside the blade shank to restrain the shaft axially and radially. The hub is provided with a number of radially extending cylindrical extensions **35**, depending on the number of blades in the rotor, and there is a bearing fixture **36** filling the space between the interior surface of the chamber **35** and the outer surface of each sleeve. The latter is attached to the blade **11** and therefore is able to feather at least through a limited arc on account of the bearing **36**. The purpose of this swing of the blade will be pointed out hereinafter.

It will be understood that if the helicopter has four blades, the hub **10** would have four compartments, equally spaced from one another, each containing a sleeve **31'** which surrounds the blade shank **33'** mounted within a bearing **36**. The shaft **31** passes through the blade shank. Thus, each blade is adapted to swing through a limited arc about its longitudinal axis, 30° as exemplified, and to carry with it the nacelle **32** and the dual propeller structure which is positioned almost at the end of the blade. The bevel gears **34**, of which there are four, mesh with a common bevel gear **37** (FIG. 6) and the latter is mounted on the shaft **8**. If desired, the large bevel gear **37** may be strengthened by the use of a circular plate **38** to which the shaft **8** is directly secured. The shaft **8** is supported in an upright sleeve **39** which flares out at the upper end into a vertically cylindrical portion **40** and an additional flared portion **41** forming part of the compartment **35**. The top of the hub **10** may be formed as a cover **41'** which can be removed, if necessary, in order to place the gear **37** and the smaller gears **34** in position. The interior of the entire hub structure is usually filled with a suitable lubricant. There is a bearing fixture **41''** interposed between the shaft **8** and the cylindrical portion **40** in order to permit the shaft freely to rotate within the hub and to carry with it the large bevel gear **37**. The lower end of the shaft may be secured through a suitable and well-known clutch for fast connect and disconnect by the action of the pilot and there is an automotive engine **42**, preferably contained in a separate compartment of the fuselage, and controlled by the flight engineer.

Thus, tracing the various mechanical connections from the engine, it will be noted that as the shaft **8** is rotated, the large gear **37** turns and will rotate all four smaller bevel gears **34**. The latter will rotate the shaft **31** to furnish rotary effort to the bevel gears **29**, and through the shaft **27** to the propellers **16**, **22**. It is apparent that the shaft **31** must necessarily be flexible so as readily to bend with the bending effects of the blades **11** and yet be sufficiently strong to furnish the necessary rotary power to the propellers. The latter are relied upon to give a vertical lift to the helicopter by causing the blades **11** to rotate at a relatively fast rate. In order to cyclically feather the blades **11** as they whirl above the helicopter body and thus accommodate the difference in lift on opposite sides of the helicopter, and to provide control of the aircraft, it is necessary to furnish a device for twisting the blades through a certain angle so that they will be inclined at this angle with respect to the direction of air flow. This is accomplished by the use of a lug **43** which extends outwardly from the edge of the blade and to which a link **44** is connected. The link **44** is held within a ball and socket joint **45** carried in an arm **46** of a swash plate generally designated at **47**, the function of which is well known in the art. The swash plate is tiltable about the arcuate bearing surface indicated at

49 and the latter forms part of a bracket 50 which is vertically slidable with respect to the sleeve 39. A drive scissors generally indicated at 51 is connected between the compartment 35 and the arm 46. The lower arm 52 is rigidly attached to the nonrotating part 48 of the swash plate 47 and is connected at the pivot 53 to a fluid piston actuator 54 which is moved by the actuator 55. The latter is servocontrolled by the pilot through the various levers 56. Thus, by operating the latter, the swash plate 47 is caused to tilt and this, in turn, will cause the link 44 to exert a push or pull on the lug 43 which will feather the blade through the limited angle desired, depending upon the amount of movement of the fluid actuator 54. It is understood for well-known reasons that the link 44 is connected to a blade displaced approximately 90° from the position of link 44.

It has been pointed out that a heavy lift or a "crane" type of helicopter is called upon to lift several tons of cargo or passengers and in order to obtain the greatest efficiency of the lifting power it is necessary to provide extremely long blades.

These blades, though made of metal and reinforced by internal struts, also notwithstanding the presence of a shaft 31 passing longitudinally therethrough, still tend to droop when the blades are slowing down and eventually come to rest. It will be understood that when the power is applied by engine 42 to the propellers 16, 22, at the end of each blade, the latter will bend upwardly, i.e., into flying position. When the blades touch at one or more places on the ground due to the extreme length of the blades, it may be impossible to start the blades rotating without damage regardless of the amount of power exerted by the engine 42.

In accordance with my invention, I provide a mechanism by which the tips of the blades can be lifted in unison so that the rotor as a whole is free of any contact with the ground regardless of the degree or the intensity of the droop. For this purpose, I provide at the rear edge of each blade a pair of control vanes indicated at 57, 58, hinged as indicated at 59, 60 to the rear edge of the blade 11 (FIG. 3). In addition, there is also a control vane 61 hinged as at 62 in any suitable manner to the lower edge of the shell 32. This vane, as well as the control vanes 57, 58, extends transversely of the rear opening in the shell 32. There is a rigid connecting bar 63 hingedly connected between the vane 58 and the vane 61. There are a pair of small shafts 64, 65 secured in any suitable manner within the blades 11 serving as a swivel for angularly shaped levers 66, 67. These levers are adapted to be rotated through 90° about the shafts 64, 65 as will be seen in FIG. 4 when the shafts 64, 65 are rotated in a manner described hereinafter.

The shafts 64, 65 are provided with bevel gears 68 (FIG. 5) and these gears mesh with a bevel gear 69 which, in turn, is rotated by means of a shaft 70 and a servomotor 71 which is electrically controlled by the pilot through the conductors 72. There is a cable 73 extending from one end of the angular lever 66. This cable passes through an eyelet 74 on the inside of the shell 32 and is affixed to the control plate 57. A similar cable 75 is secured to the leg of the angular lever 66 and passes through an eyelet 76 at the lower inside surface of the shell 32 and is affixed to the underside of the control plate 57. A cable 77, affixed to one end of the angular lever 67, passes through an eyelet 78 at the underside of the shell 32, and is secured to the upper surface of the control plate 58. It is apparent that when each of the shafts 64, 65 is caused to rotate by means of the servomotor 71 (FIG. 5) and the arcuate levers rotated 90° in the clockwise direction, the cable 73 will permit the control plate 57 to be lowered and the cable 75 will exert a pull on the same control plate on account of the lower end of the arcuate lever being moved upwardly to the horizontal direction, which operation is shown in FIG. 4. Likewise, the cable 77 will be caused to move upwardly when the angular lever is rotated clockwise through 90° and this will permit the control plate 58 to move downwardly and to carry with it the connecting rod 63 which, in turn, will swing the control plate 61 about the pivot 62 so that the control plates 57, 58, 61 are now directed downwardly in unison to a position shown in FIG. 4. Assuming that the propellers 16, 22 which now take on the role of fans, have been rotating and sending a flow of air of annular shape through the rear end of the shell 32, the directing vanes will cause a part of this air flow to be deflected downwardly as indicated at 79 toward the ground. The reaction of the blade tip to this downward air motion would be to lift the outer tip of the blade at least a distance sufficient to clear the ground so that the rotor is then free to turn due to the tangential thrust component of the fans. It will be understood that the fans 16, 22 would be operated at reduced power during this operation but, together with the normal resiliency at the end of the long blade, any obstruction, even though sizeable, could be cleared without damage to the blade. Thus, the lifting power exerted at the blade tips can be controlled to prevent any damage to the blades.

It is apparent that by providing the propellers operating in opposite directions that gyroscopic effects can be minimized or eliminated.

Instead of providing a pair of engine-driven fans for the reaction drive system, it is possible, in accordance with another aspect of my invention, to employ a different source of power to provide the blade uplift. In FIGS. 7 and 8, there is shown the use of a turbojet as the driving power of each of the blades and it will be understood that, if desired, turbofans may also be provided for the same purpose.

Most of the jet stream from the turbojet is employed to lift each blade tip clear of the ground and obstructions. A brake (not shown) is provided at the hub to prevent rotation of the rotor until desired by the pilot. In FIG. 7, there is shown a typical turbojet and the outline of the blade is also indicated by dotted line to show the relative position between the turbojet and the blade. In this figure, reference character 80 shows generally the compressor stage of a typical turbojet. The combustion chamber which furnishes the gas under high pressure, and therefore high velocity, is generally indicated at 81. The fuel is burned by means of a spark plug 82 and the admitted gases strike a turbine wheel 83 which causes the latter to rotate and to carry with it the shaft 84 and the enlarged conical shaft extension 85. Compressor blades 86 of varying diameter are attached to the shaft member 85 within the casing 88. As air is drawn into the compressor, as indicated by arrow C, it is compressed by the blades of the latter and passes through the annular nozzle 88' to increase the speed of the air. Assuming that fuel has been introduced into the chamber 81, and burned in the presence of the compressed air, a fast-moving jet is produced, a part of which strikes the turbine 83. The compressor shaft 85 is thereby rotated since it is driven by the turbine. The jet is directed by the tail cone 89 and the tail pipe 90 to provide a strong driving thrust, as indicated at 91'. This jet stream provides the driving force by which the blades 11 are caused to rotate about the shaft 91 (FIG. 8). It will be noted that the turbojet device is located at or near the outboard extremity of each helicopter blade. In order to supply fuel to the combustion chamber of the turbojet, a pipe 92 is taken from that chamber through the blades and into the hub 93. The pipes from all four blades merge in a pump 94, and a pipe 95 from the latter passes to a suitably located fuel reservoir which is typically illustrated as a chamber 87 forming part of the hub structure. Thus, the fuel can pass through the pipe 95, pump 94 and the pipe 92 to each of the turbojets. The hub structure 93 may be similar to that described in detail in FIG. 6 except that the gearing has been eliminated and the shaft 91 merely serves as a rigid stanchion for the rotating hub and the blades attached thereto. The blades 11 are swingably mounted within the

hub **93** and can be moved in one direction or the other about the longitudinal axis by means of a swash plate **47** and the necessary operating mechanism indicated at **54, 55** and **56** shown in FIG. 6. The parts in FIG. 8, which have not been described, are given the same reference characters as the corresponding parts in FIG. 6.

In order to divert an appreciable part of the jet stream toward the ground so as to lift the tips of the blades from the ground, a laterally extending vane **96** of metal (FIG. 7) is provided across the upper edge of the nozzle so that the jet stream, at least in part, will be redirected as indicated at **97** toward the ground. The vane **96** could be rigidly fixed to the nozzle but preferably would be hinged at the top and by the use of cables (not shown) the vane could be elevated to a horizontal position so as not to interfere with the full drive of the jet stream when the helicopter is in flight. Even a small amount of deflection of the jet stream would ordinarily be sufficient to free any ground contacting blade tip or tips, with the brake engaged to prevent rotor rotation, so that the interference with the normal flow of the jet stream would be kept to a minimum, even when using a fixed vane. It will be obvious that the turbojet may be affixed to the end of the blade in any suitable manner as by bolting the casing **88** to the helicopter blade.

While I have shown the use of an engine driven fan or propeller structure as the thrust driver of the blades in FIGS. 1, 2, 3, 4 and 6, also the use of a turbojet thrust driver in FIGS. 7 and 8, it is obvious that, if desired, a turbofan or open propeller could be used for the same purpose, in which case a portion of the air flow would be deflected in the same manner as described in connection with FIGS. 7 and 8 to provide the lifting force at the ground in order to clear the blade tips from the ground.

Moreover, it is further evident that while I have shown the use of two fans rotated in opposite directions to reduce or eliminate the gyroscopic effect in connection with FIGS. 1, 2, 3 and 4, that a single fan could be substituted or, for that matter, any number of fans could be used at the outboard portions of the blades either in coaxial or parallel shaft arrangement.

In FIGS. 9 to 11, I have shown a modified form of structure by which the blade tips can be elevated when necessary. The various parts will be given the same reference characters as the elements of FIG. 3 which have the same function.

The tip end of one of the blades is shown at **11** and it will be understood that the blade passes into a hub structure **10** (FIG. 6) together with other blades of similar construction, and the hub contains gearing **34, 37** coupled to the engine **42**, together with the various control devices as explained in connection with FIG. 6. A thrust driving structure is contained within a shell or shroud **32** from which struts **33** are taken to support an elliptically shaped nacelle **12**. Within the latter there is another elliptically shaped member **100** which may, if desired, have the same cross-section as a blade in order to provide streamlined effects in conjunction with the shape of the nacelle. The member **100** is supported within the nacelle by struts **101** and would normally be constructed of heavier material than the nacelle in order to contain heavy gearing. The latter is constituted of a pair of bevel gears connected to shaft **103, 104** which are journalled in lugs **105**. The shafts pass through suitable bearings (not shown) to conically shaped caps **106** which carry propeller blades **107**. The bevel gears **102** engage a centrally positioned bevel gear **108** carried on a shaft **109** which extends transversely of the member **100**, the nacelle and the shell **32**. A large circular boss **110** may be provided on the external surface of the shell and it is bored to receive the shaft. The boss terminates in a flat shoulder adjacent to but spaced slightly from the end of the blade **11**. A tubular member **111** is integrally secured to the boss **110** and extends into the interior of the blade **11**. This member is supported on a bearing **112** preferably of the well-known angular contact type which is contained within an inwardly projecting boss **113** formed as part of a wall **114**. The latter closes off the end of the blade **11**. The inner end of the member **111** is carried on a bearing **115** which is supported within a thickened portion of a narrow web **116**. The latter extends across the interior of the wide portion of the blade to which it is secured. This web also serves as an end support for two additional stub shafts **117, 118**. The opposite ends of these shafts are supported in a second web member **119**. The purpose of these shafts will be explained presently. The shaft **117** at its center carries a gear **120** and the shaft **118** is provided with a gear **121** which engages gear **120** and is driven by a servomotor **122**. Conductors **123'** are taken from the latter to the cockpit of the helicopter in order to control the motor. The shaft **109** passes through the web **119** and is provided with a gear **124** positioned between the webs and is loose on the shaft. The tubular member **111** is affixed to this gear and is free to rotate on the shaft **109** so that when the servomotor **122** is operated by the pilot, rotary motion is imparted through the gears **121, 120, 124** and the tubular member **111** to the shell **32**. A comparison between FIGS. 9 and 11 will show the shell as having been rotated 90° from a position parallel to the wide flat surface of the blade to a position at a right angle thereto. However, in practice, the shell would most likely, be turned to an angular position less than 90°, just sufficient to permit the downward flow of air to raise the tip of the blade or blades to effect the proper clearance from the ground. The shell and the contained fans are then returned to their flying position in which the fans perform the function of propellers.

The shaft **109** is power driven by the engine **42** (FIG. 6) through the gearing **37, 34** so that the propellers **107** (FIG. 9) are rotated in opposite directions as was explained in connection with FIG. 6.

In FIGS. 12 to 14, there is shown the manner in which a jet actuator can be rotated from a position substantially parallel to the flat side of the blade (FIGS. 12 and 13) to a position at a right angle thereto (FIG. 14) or to any other angular position so that the jet stream can be temporarily pointed downward. A large boss **124'** is welded to the external surface of the jet motor and, as in the case of FIG. 9, this boss is caused to rotate by the tubular member **111** and the gearing **121, 120** and **124** when the servomotor **122** is energized from the pilot's position. A conduit **123** leads back to a suitable source of fuel **87** (FIG. 8) and is provided with a swivelable gas-tight seal **125** of any suitable and well-known type. Thus, when fuel is admitted to the combustion chamber **81**, the explosive gases initiated by one or more spark plugs **82** will pass through the nozzle at high speed and will impinge on the turbine wheel **83**. The latter rotates the compressor **80** (FIG. 7) to furnish air under high pressure to the combustion chamber to intensify the burning of the gas which results in a jet issuing from the tail pipe **90**. This jet constitutes a thrust driver which when projected downwardly to any appropriate angle, determined by the movement of the servomotor, the tip of the blade is caused to elevate and thus clear any ground obstruction. It will be understood that as in the case of the fan or propeller actuator, a suitable and well-known form of brake (not shown) is desirable to prevent any tendency of the rotor to turn during the tip-lifting operation. The jet actuator is then rotated in the reverse direction to its normal flying position in order to turn the rotor hub and the associated blades.

It is apparent that instead of a jet device, as described, for turning the blade assembly and when physically rotated to direct a stream of gas downwardly to elevate the blade tips, a turbofan may also be employed for the same purpose and using similar controls as set forth herein.

I claim:

1. A helicopter in which the blades have a large droop factor, means for lifting the outboard section of each

blade using vectorable thrust, said means including a thrust-producing device in the region of the blade tip, and means controlling the thrust output of said device to keep the blade extremities above the ground and any obstruction when the rotor speed is insufficient to avoid such contact.

2. A helicopter according to claim 1 and in which the first-mentioned means is constituted of a fan device supported by the blade, the second-mentioned means being constituted of a deflecting vane positioned in the path of the airstream projected by said fan device.

3. A helicopter according to claim 1 and in which the first-mentioned means is constituted of a jet device supported by the blade, the second-mentioned means being constituted of a deflecting vane attached to the jet device and positioned angularly with respect to the path of the jet stream.

4. A helicopter according to claim 2 and in which the said deflecting vane is positioned angularly with respect to the direction of the airstream, and the angularity of the vane is controllable by the pilot.

5. A helicopter according to claim 1 and in which said thrust-producing device is constituted of a fan rotatably mounted on a nacelle attached to each helicopter blade in the region of the blade tip, a shroud surrounding the tips of the fan blades, for deflecting at least a portion of the thrust output of said fan toward the ground, and means positioned within the cockpit of the helicopter for changing the deflection of said means in order to control the amount of air being driven downwardly from the main stream whereby the tip of each blade is controllably lifted toward its normal flight position.

6. A helicopter according to claim 1 and in which the first-mentioned means is constituted of a fan device physically separate from the rotor blade but rotatably mounted on the end of the blade, and means operable from the cockpit for rotating the fan device to such angle as to project a flow of air downwardly whereby the tip of the blade can be elevated.

7. A helicopter according to claim 6 and in which said fan device can be rotated by said rotating means to a position as will cause the fan device to serve as a thrust producer for driving the lifting rotor.

8. A helicopter according to claim 1 and in which the first-mentioned means is constituted of a jet device physically separate from the blade but rotatably mounted on the end of the blade, and means for rotating the jet device from the position of the cockpit to such angle as to project a stream of gas downwardly whereby the tip of the blade can be elevated.

9. A helicopter according to claim 8 and in which said jet device can be rotated by said rotating means to a position as will cause the jet device to serve as a thrust producer for driving the lifting rotor.

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