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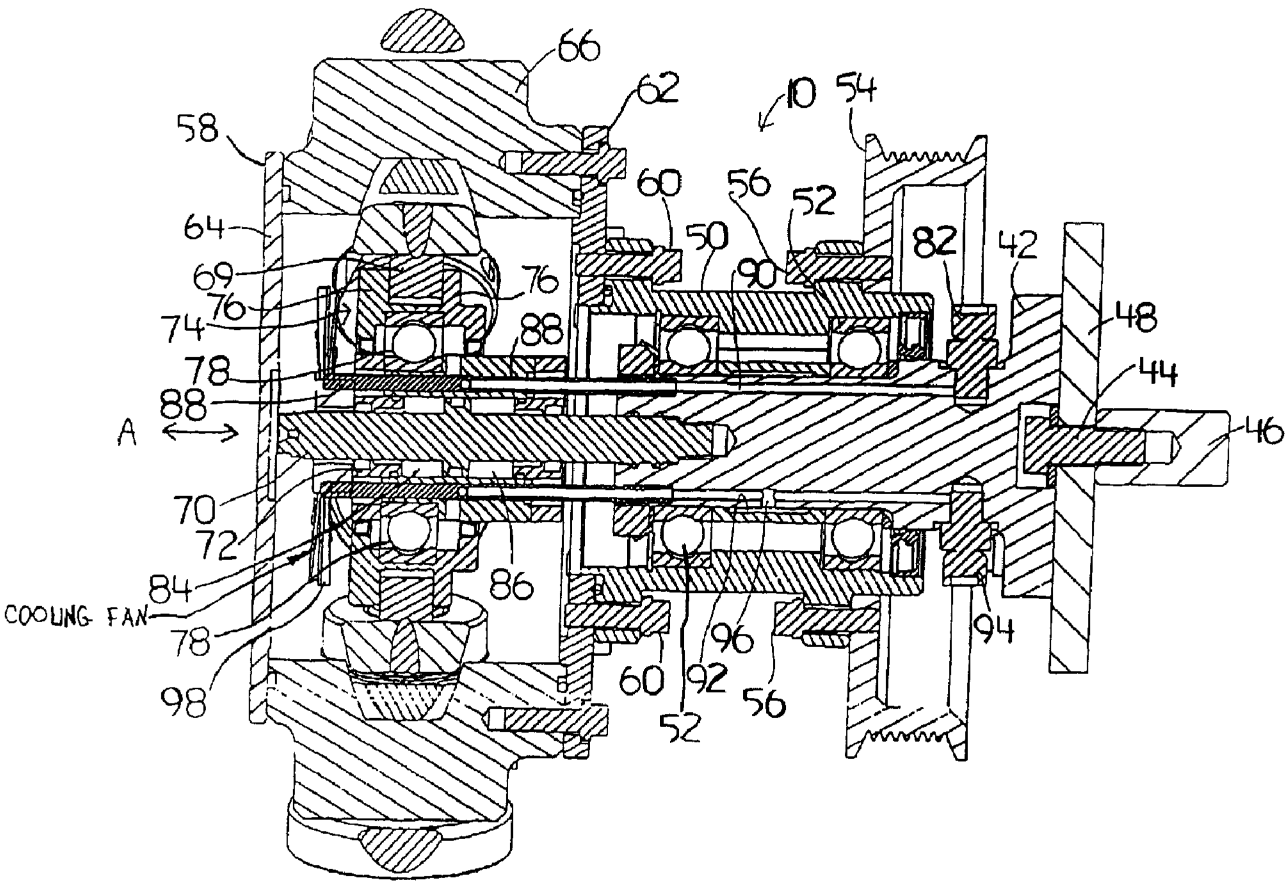
(54) Title: VARIABLE PITCH FAN



(57) Abrégé/Abstract:
A variable pitch fan in which the pitch of the fan blades is varied under control of a controller according to the speed of the fan. The controller is programmed to respond to increased fan speed by decreasing pitch of the fan blades. The variable pitch fan has a

(57) Abrégé(suite)/Abstract(continued):
piston extending axially from a main shaft, about which main shaft a fan blade hub rotates. A pitch shifter is mounted on a cylinder, which itself is mounted on the piston. The pitch shifter is actuated by hydraulic fluid supplied through the main shaft to the cylinder. The piston is preferably axially stationary in relation to the main shaft. The cylinder is secured against rotational movement by at least one guide pin passing into the main shaft. Grease for the pitch shifter is supplied through the guide pin. One guide pin may be used for grease supply, while another may be used for excess grease return. Cooling of a pitch shifter may be accomplished using a heat sink mounted within the fan hub, preferably in a fan configuration, to conduct heat away from the cylinder into air rotating within the fan hub. Counterweights are mounted on each fan blade of a variable pitch fan, preferably hydraulically actuated, in a position which generates a torque opposite in direction to torque generated by the fan blades. The counterweights may be overbalanced, underbalanced, or balanced.

ABSTRACT OF THE DISCLOSURE

A variable pitch fan in which the pitch of the fan blades is varied under control of a controller according to the speed of the fan. The controller is programmed to respond to increased fan speed by decreasing pitch of the fan blades. The variable pitch fan has a piston extending axially from a main shaft, about which main shaft a fan blade hub rotates. A pitch shifter is mounted on a cylinder, which itself is mounted on the piston. The pitch shifter is actuated by hydraulic fluid supplied through the main shaft to the cylinder. The piston is preferably axially stationary in relation to the main shaft. The cylinder is secured against rotational movement by at least one guide pin passing into the main shaft. Grease for the pitch shifter is supplied through the guide pin. One guide pin may be used for grease supply, while another may be used for excess grease return. Cooling of a pitch shifter may be accomplished using a heat sink mounted within the fan hub, preferably in a fan configuration, to conduct heat away from the cylinder into air rotating within the fan hub. Counterweights are mounted on each fan blade of a variable pitch fan, preferably hydraulically actuated, in a position which generates a torque opposite in direction to torque generated by the fan blades. The counterweights may be overbalanced, underbalanced, or balanced.

TITLE OF THE INVENTION

Variable Pitch Fan

FIELD OF THE INVENTION

This invention relates to variable pitch fans.

BACKGROUND OF THE INVENTION

Caterpillar Inc. of Peoria, Illinois makes a variable speed clutched fixed pitch fan (CAT fan). As an engine to which the fan is attached speeds up, the fan clutch begins to slip, thus maintaining the fan at a desired rpm, avoiding power waste and excessive noise.

There are various variable pitch fans known, as for example those described in United States patent nos. 5,564,899; 5,022,821; and 5,122,034. It is an object of the invention to provide improved operating features for variable pitch fans.

SUMMARY OF THE INVENTION

Flexxaire Manufacturing Inc. makes a variable pitch fan for use on engines, such as engines made by Caterpillar Inc. Since Flexxaire's variable pitch fan must deliver the same amount of air flow as the CAT fan at lower RPMs, the fan ends up delivering excess air with high noise generation at higher rpm because the fan speed on the Flexxaire variable pitch fan cannot be clutched. The inventor has identified this problem and proposed a solution by controlling the pitch of its variable pitch fan based on rpm. This will reduce power consumption and noise generation. By this invention, maximum air flow may be achieved at lower engine speeds, inherent losses from using a clutch are avoided, and better control of air flow is achieved.

There is thus provided, in accordance with an aspect of the invention, a variable pitch fan in which the pitch of the fan blades is varied under control of a controller according to the speed of the fan. The controller is programmed to respond to increased fan speed by decreasing pitch of the fan blades.

A goal of variable pitch fan design is to provide a variable pitch fan which is lightweight, reliable, and which provides accurate and rapid adjustment of fan pitch. According to a further inventive step, there is provided a variable pitch fan, which has a piston extending axially from a main shaft, about which main shaft a fan blade hub rotates. A pitch shifter is mounted on a cylinder, which itself is mounted on the piston. The pitch shifter is actuated by hydraulic fluid supplied through the main shaft to the cylinder. The piston is preferably axially stationary in relation to the main shaft.

According to a further aspect of the invention, the cylinder is secured against rotational movement by at least one guide pin passing into the main shaft.

According to a further aspect of the invention, grease for the pitch shifter is supplied through the guide pin. One guide pin may be used for grease supply, while another may be used for excess grease return.

According to another inventive step, cooling of a pitch shifter may be accomplished using a heat sink mounted within the fan hub, preferably in a fan configuration, to conduct heat away from the cylinder into the air rotating within the fan hub.

According to a further inventive step, counterweights are mounted on each fan blade of a variable pitch fan, preferably hydraulically actuated, in a position which generates a torque opposite in direction to torque generated by the fan blades. The counterweights may be overbalanced, underbalanced, or balanced.

These and other aspects of the invention are described in the detailed description of the invention and claimed in the claims that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

There will now be described preferred embodiments of the invention, with reference to the drawings, by way of illustration only and not with the intention of limiting the scope of the invention, in which like numerals denote like elements and in which:

Fig. 1 is a schematic of a variable pitch fan assembly with pitch actuator and controller in accordance with the present invention;

Fig. 2 is a flow diagram showing operation of a controller for controlling pitch in accordance with RPM;

Fig. 3 is a first cross-section through a hydraulically actuated variable pitch fan with stationary piston showing grease galleries;

Fig. 4 is a second cross-section of the variable pitch fan shown in Fig. 4 showing hydraulic supply lines;

Fig. 5 is a perspective of the variable pitch fan shown in Figs. 3 and 4;

Fig. 6 is a perspective view of a fan blade with counterweights according to an aspect of the invention;

Fig. 7 is a section through a fan blade with counterweights as shown in Fig. 6; and

Fig. 8 is a section through a hydraulically actuated variable pitch fan with stationary cylinder.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Fig. 1, an engine 12 and variable pitch fan assembly 10 are positioned within an engine compartment of vehicle, for example a piece of heavy wheeled or tracked equipment. Variable pitch cooling fan 10 with its blades 14 is disposed within the engine compartment and attached to engine 12. The blades 14 of cooling fan 10 have a plurality of blade positions, including a push position (reverse blade position), pull position (conventional or normal position) and neutral position in which the rotation of the blades continues and blocks air flow (air block effect). The pitch of the blades 14 may be varied in small angular increments by actuator 16. A controller 20 is coupled to cooling fan 10 by means of a communications link 22 (for example a cable) which connects to actuator 16 and serves to adjust the positioning of fan blades 14 by providing signals to the actuator 16 along link 22. A conventional speed or rpm sensor 24 is provided on the engine for sensing the engine RPM. Sensor 24 is coupled to controller 20 by means of a further communications link such as cable 26. Controller 20 receives power from battery 17. The pitch actuator 16 is connected to the fan 10 by hydraulic supply lines 19.

Referring to the flow diagram in Fig. 2, the controller 20 works as follows. Air flow requirement is determined initially at 30 from various conventional sensors of cooling requirement such as engine coolant temperature, intake air temperature, hydraulic oil temperature, transmission oil temperature, brake coolant temperature, pressure or AC condenser temperature or any other sensor that indicates a cooling load. This is known in the art. Flexxaire Manufacturing Ltd. of Edmonton, Canada, has for example provided a variable pitch fan assembly with thermostatic pitch controller that controls the pitch of the fan dependent upon engine temperature since at least as early as 1990. Unlike previous fans, the present fan also decreases fan pitch in response to increased measured RPM as determined by the RPM sensor 24. RPM is sensed in step 32. This RPM sensor 24 senses the speed of the engine. However, it is equivalent to a fan speed sensor since the engine speed directly controls the fan speed (due to a direct belt and pulley connection). Given the cooling requirements determined by the various conventional temperature and/or pressure sensors in step 30, the controller 20 calculates in step 34 the total air flow and hence required pitch to cool the engine at the current RPM. The determined pitch is then compared with the actual pitch in step 36. If the pitch is too low, it is increased, if too high, it is decreased, otherwise it is left the same. Pitch is increased or decreased in step 38 by manipulating hydraulic solenoid valves in the pitch actuator 16. The pitch actuator 16 is formed of a conventional hydraulic supply controlled by solenoid valves. The solenoid valves are controlled by signals from the controller 20.

By being able to control pitch based on RPM, the present device is able to clip the pitch at high RPM. This saves horsepower and is better than a clutched fan because a slipping clutch inherently wastes energy, and also reduces sound due to the lower air flow. Maximum air flow may then be obtained at lower engine (fan) speeds without clutch slipping losses.

Referring now to Figs. 3-5, a variable pitch fan 10 has a main shaft 42 with an axis A. At one end of the main shaft 42 is a mechanism for securing the fan 10 to a vehicle using bolt 44 embedded in a recess 46. The bolt 44 threads into a nut 46 and is used to secure the fan 10 to a wall 48 of an engine compartment 12. A cylindrical flanged housing 50 is rotatably mounted on the main shaft 42 with main shaft bearings 52. A pulley hub 54 is secured to the cylindrical flanged housing 50 with bolts 56 or other suitable means. A fan hub 58 is secured to the cylindrical flanged housing 50 with bolts 60 or other suitable means. The fan hub 58, pulley hub 54 and housing 50 rotate together on the main shaft 42. The fan hub 58 is formed of an annular plate 62, circular plate 64 and cylindrical fan blade housing 66 secured between the annular plate 62 and circular plate 64. A number of fan blades 14, for example six, extend radially from the fan hub 58. The fan blades 14 are mounted to rotate about the fan blade long axis with fan blade shafts 67 received within bores 68 formed in the fan hub 58. The fan blade shafts 67 terminate inwardly with axially offset shifter pins 69. Suitable seals and bearings are used to permit the fan blades 14 to rotate in bores 68 and thus change or adjust pitch of the fan blades 14.

A piston 70 extends axially (along axis A) from the main shaft 42. In the embodiment shown in Figs. 3 and 4, the piston 70 is fixed stationary to the main shaft 42. A double acting cylinder 72 is mounted on the piston 70. The cylinder 72 shown in Figs. 3 and 4 is slidably mounted to allow for relative axial movement between the piston and cylinder. In the instance shown, the cylinder moves in relation to the piston 70. A pitch shifter 74 is mounted on the cylinder 72. The pitch shifter 74 is formed of a pair of parallel plates 76 mounted on pitch shifter bearings 78. The pitch shifter 74 interconnects the cylinder 72 and the fan blades 14 to convert axial movement of the cylinder 72 to a pitch change of the fan blades 14. Referring to Fig. 4, hydraulic lines 80 pass through the main shaft 42 from a hydraulic supply fitting 82 to both chambers 84 and 86 of double acting cylinder 72. The piston 70, cylinder 72, pitch shifter 74, bearings 78 and pins 69 together form a pitch shifter mechanism for the pitch adjustable fan blades 14.

In operation, the cylinder 72 is driven axially back and forward on the piston 70 by hydraulic fluid delivered from the pitch actuator 16 (Fig. 1). Preferably, neither the piston 70 nor the cylinder 72 rotate with the fan hub 58. The pitch shifter 74 rotates with the fan hub 58 and translates with the movement of the cylinder 72. As the pitch shifter 74 is driven axially by the cylinder 72, the pins 69 are also driven axially, which forces the blades 14 to rotate and adjust the pitch of the fan blades 14.

As shown in Figs. 3 and 4, the cylinder 72 is secured against rotational movement by at least one guide pin, here shown as two pins 88, passing from the cylinder 72 into the main shaft 42. Referring to Fig. 3, a grease gallery 90 is provided in the main shaft 42 extending from the fitting 82 and interconnecting with the pitch shifter bearings 78 through at least one of the guide pins 88. A second grease gallery 92 extends from the shifter bearings 78 through the other of the guide pins 88 to fitting 94. A port 96 in the gallery 92 allows excess grease from the shifter bearings 78 to lubricate the main shaft bearings 52.

A heat sink formed of aluminum fan shaped air deflectors 98 is mounted within the fan hub 58 on the cylinder 72 to conduct heat away from the cylinder 72 into the air rotating within the fan hub.

Referring now to Figs. 6 and 7, counterweights 100 are mounted on each fan blade 14 in a position which generates a torque opposite in direction to torque generated by the fan blades 14. Each fan blade 14 has a chord B and the counterweights 100 are mounted perpendicular to the chord B on either side of the fan blade 14. The weight of the counterweights 100 may be selected to underbalance, balance or overbalance the blades 14.

Due to the shape of a fan blade 14, the centrifugal forces produced when the fan hub 58 spins generates a torque on the fan blades 14 which tends to force the fan blades 14 to a neutral pitch. This force increases with the square of the RPM and is related to the shape and mass of the blade according to known principles in the art of making aircraft propeller blades. By varying the size and placement of the counterweights, the weights may be underbalanced, balanced, or overbalanced, corresponding to whether the torque generated by the counterweights is less than, equal to or greater than the torque generated by the blades. In the underbalanced condition, there is a net torque driving the blades to neutral pitch and in the overbalanced condition, there is a net torque driving the blades to full pitch.

In the underbalanced condition, the counterweights reduce the force required to hold the blades in full pitch, but at the same time keep the weights below the balance point, so that the blades default to neutral pitch. This is useful for open loop control systems. Without sensors, neutral pitch is unattainable if the blades are balanced or overbalanced. By keeping the blades underbalanced, neutral pitch can be achieved simply by removing positioning control and letting the blades rotate freely. In hydraulic applications, this is achieved simply by equalizing the pressure on each side of the piston. A simple control system can then achieve full pitch in either direction depending on which side of the piston receives the high pressure fluid, and can achieve neutral pitch by equalizing the pressure on each side of the piston, i.e. by using simple valving.

In the balanced condition, the force required to hold the blades in any pitch can be dropped effectively to zero. Balanced blades require the lowest pitch adjustment forces, and thus smaller components, and in the case of hydraulic systems, lower operating pressures.

In the overbalanced condition, the blades drive into pitch. This is advantageous in that the fan then defaults to full pitch in case of shifter mechanism failure. For the hydraulic fan, if a leak occurred or hydraulic pressure failed, the fan defaults to full pitch and a potential over heat condition can be avoided.

Referring now to Fig. 8, an embodiment is shown in which the piston 112 is axially movable within a bore formed in main shaft 114. A stationary cylinder 116 is fixed to the main shaft 114. In this instance, the pitch shifter 118 is attached to the piston, and stabilized with pins 120 that extend from the pitch shifter 118 to the cylinder 116. In this case, the cylindrical housing to which the pulley hub 54 and fan hub 66 is attached is formed of two parts 122 and 124. In addition, hydraulic fluid is supplied through channel 126 from the pitch actuator 16 to move the piston to the right in the figure and through channel 128 to move the piston the left in the figure. Grease may be supplied to the pitch shifter bearings 134 through a channel 132 running along the axis of the piston 112. Grease and hydraulic fluid may be fed to the respective channels through fitting 130. Otherwise, the parts of the embodiment shown in Fig. 8 function in the same manner as the embodiment shown in Figs. 3 and 4.

A person skilled in the art could make immaterial modifications to the invention described here without departing from the essence of the invention.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A variable pitch fan, comprising:

a main shaft having an axis;

a pulley hub and fan hub mounted for rotation together on the main shaft;

a plurality of fan blades mounted with adjustable pitch on the fan hub;

a pitch shifter mechanism mounted on the main shaft and interconnecting with the fan blades to effect pitch adjustment of the fan blades; and

counterweights mounted on each fan blade in a position which generates a torque opposite in direction to torque generated by the fan blades.

2. The variable pitch fan of claim 1 in which each fan blade has a chord and the counterweights are mounted perpendicular to the chord.

3. The variable pitch fan of claim 1 in which the counterweights underbalance the blades.

4. The variable pitch fan of claim 1 in which the counterweights balance the blades.

5. The variable pitch fan of claim 1 in which the counterweights overbalance the blades.

6. A variable pitch fan, comprising:

a fan hub;

a plurality of fan blades mounted with adjustable pitch on the fan hub;

a pitch shifter mechanism mounted on the fan hub and interconnecting with the fan blades to effect pitch adjustment of the fan blades; and

counterweights mounted on each fan blade in a position which generates a torque opposite in direction to torque generated by the fan blades.

7. The variable pitch fan of claim 6 in which each fan blade has a chord and the counterweights are mounted perpendicular to the chord.

8. The variable pitch fan of claim 6 in which the counterweights underbalance the blades.

9. The variable pitch fan of claim 6 in which the counterweights balance the blades.

10. The variable pitch fan of claim 6 in which the counterweights overbalance the blades.

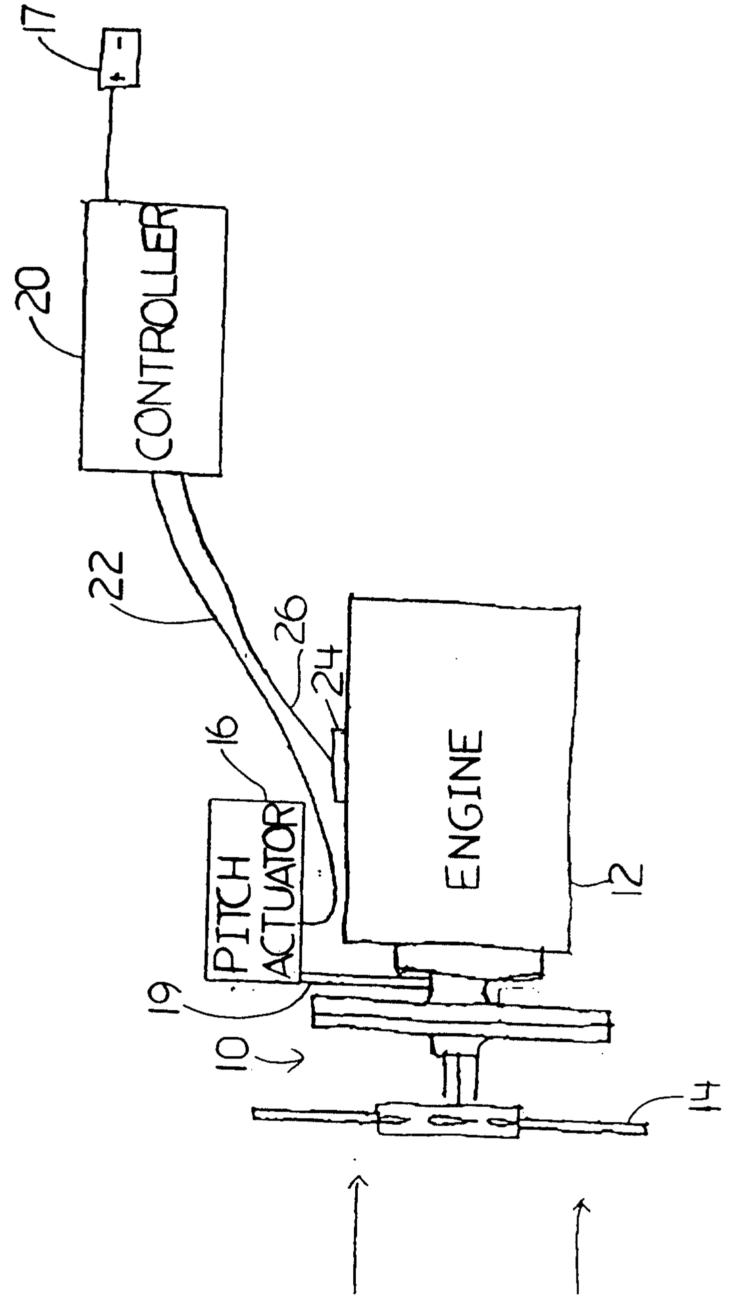


FIGURE 1

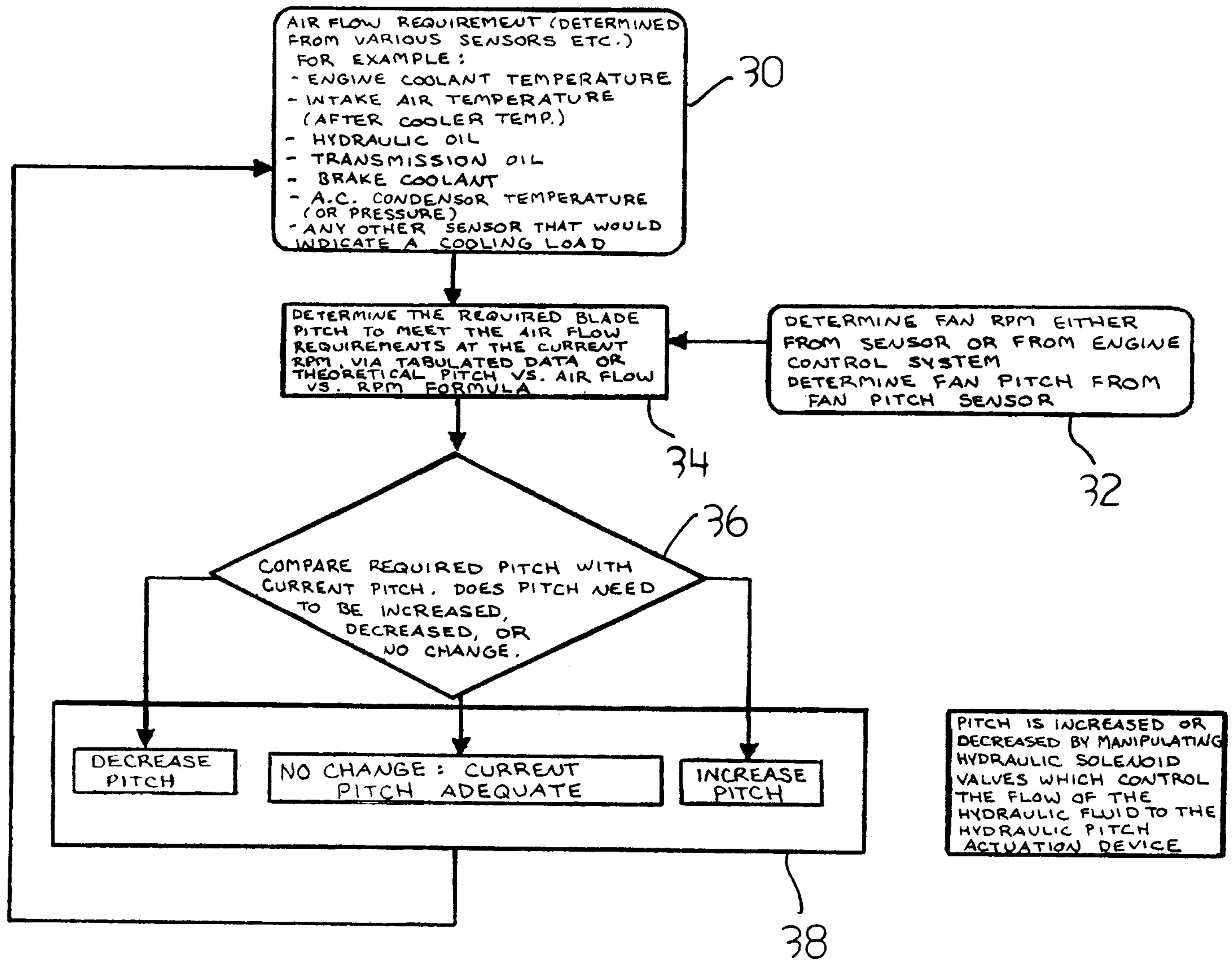
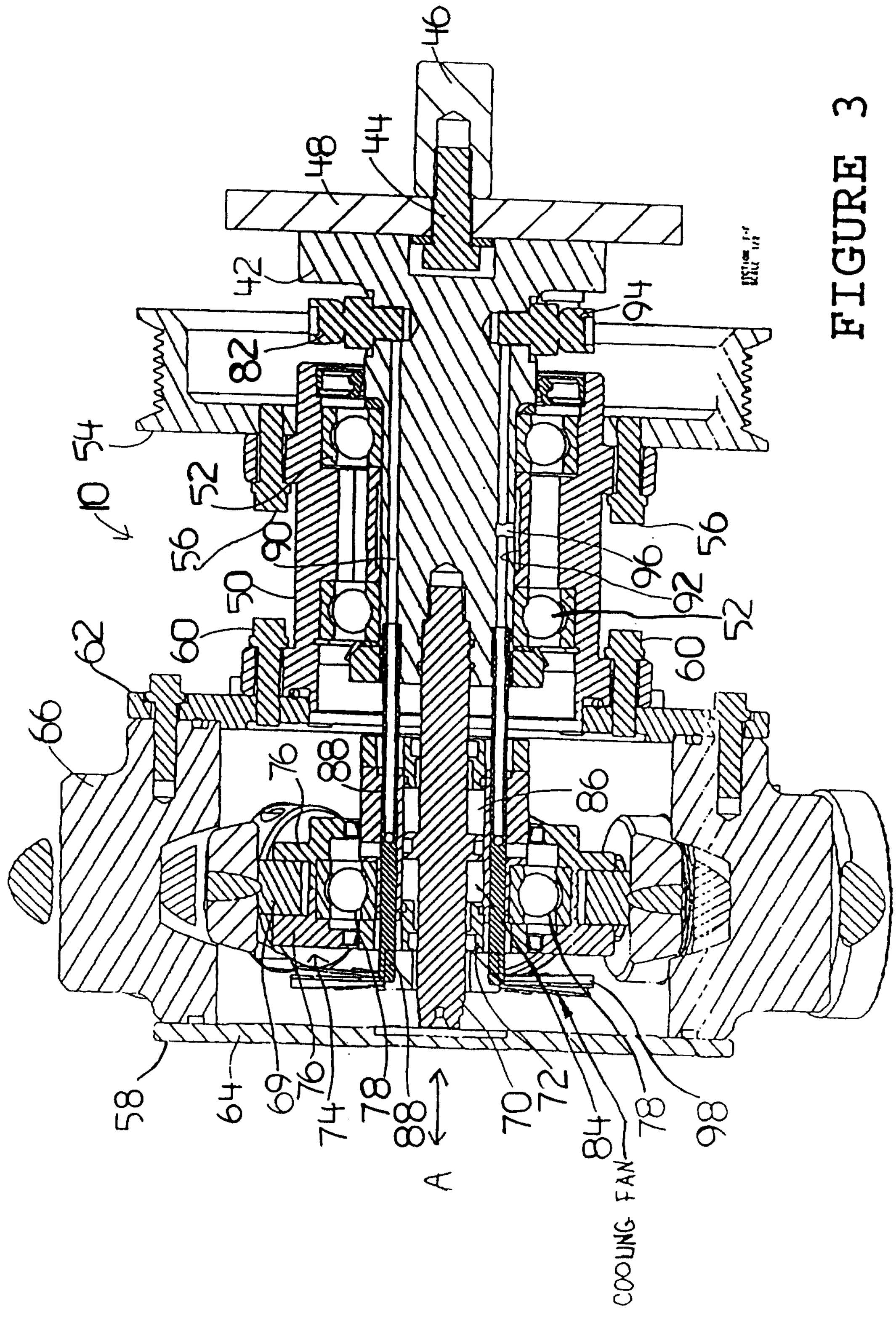

AIR FLOW REQUIREMENT (DETERMINED FROM VARIOUS SENSORS ETC.)
FOR EXAMPLE:
- ENGINE COOLANT TEMPERATURE
- INTAKE AIR TEMPERATURE (AFTER COOLER TEMP.)
- HYDRAULIC OIL
- TRANSMISSION OIL
- BRAKE COOLANT
- A.C. CONDENSOR TEMPERATURE (OR PRESSURE)
- ANY OTHER SENSOR THAT WOULD INDICATE A COOLING LOAD
30
DETERMINE THE REQUIRED BLADE PITCH TO MEET THE AIR FLOW REQUIREMENTS AT THE CURRENT RPM, VIA TABULATED DATA OR THEORETICAL PITCH VS. AIR FLOW VS. RPM FORMULA
34
DETERMINE FAN RPM EITHER FROM SENSOR OR FROM ENGINE CONTROL SYSTEM
DETERMINE FAN PITCH FROM FAN PITCH SENSOR
32
COMPARE REQUIRED PITCH WITH CURRENT PITCH. DOES PITCH NEED TO BE INCREASED, DECREASED, OR NO CHANGE.
36
DECREASE PITCH
NO CHANGE: CURRENT PITCH ADEQUATE
INCREASE PITCH
38
PITCH IS INCREASED OR DECREASED BY MANIPULATING HYDRAULIC SOLENOID VALVES WHICH CONTROL THE FLOW OF THE HYDRAULIC FLUID TO THE HYDRAULIC PITCH ACTUATION DEVICE

FIGURE 2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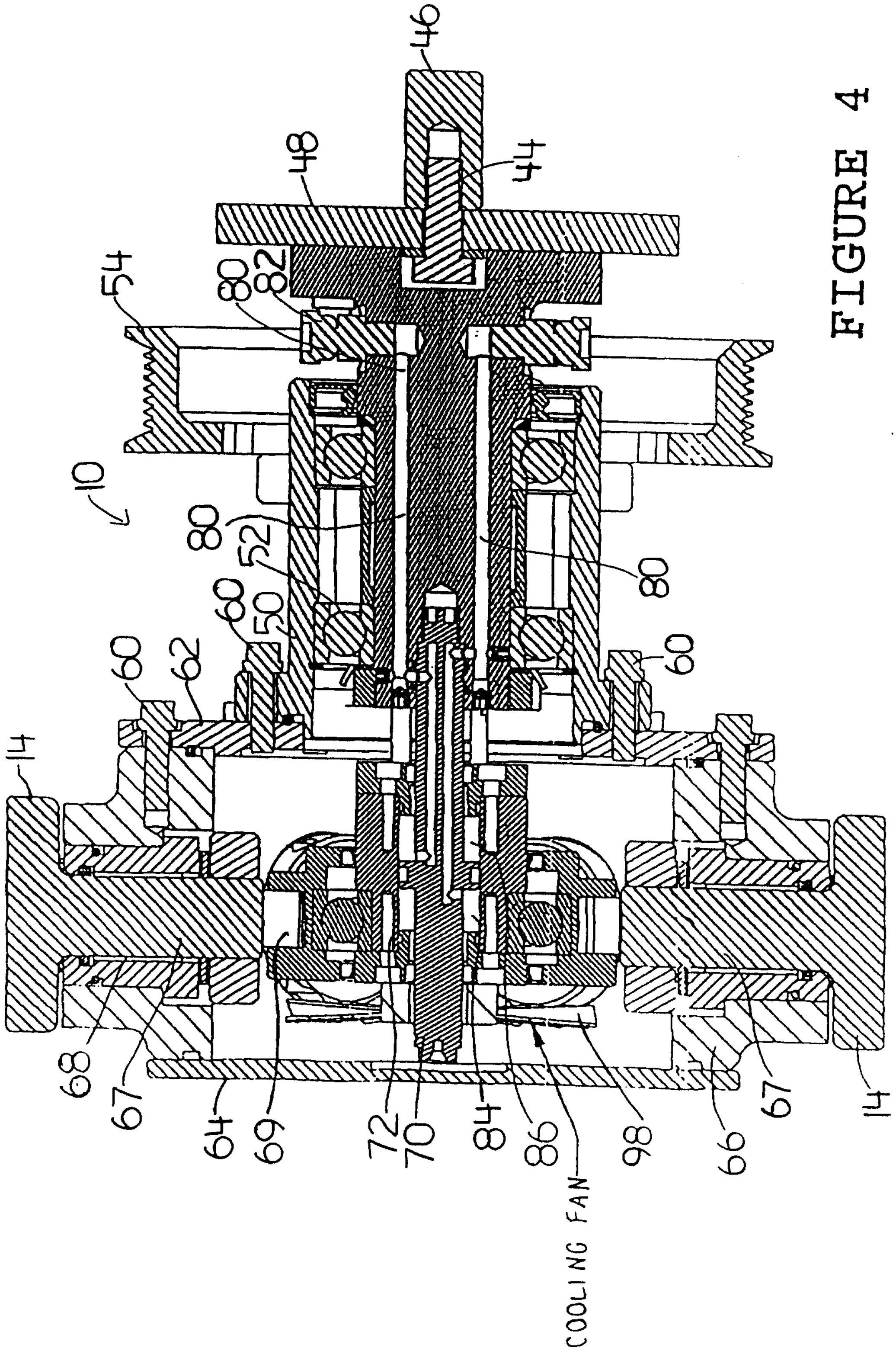
COOLING FAN

FIGURE 3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COOLING FAN

FIGURE 4

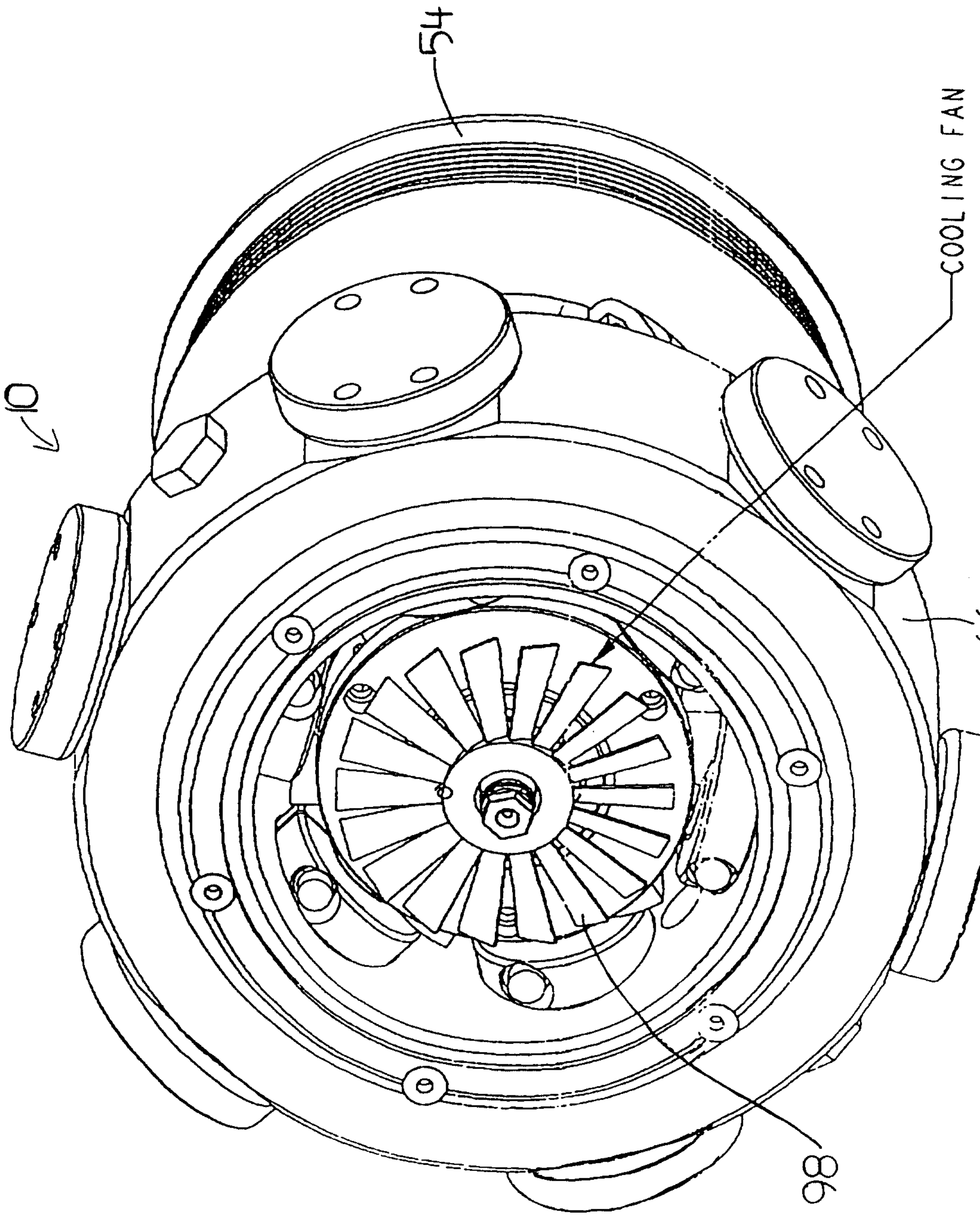

FIGURE 5

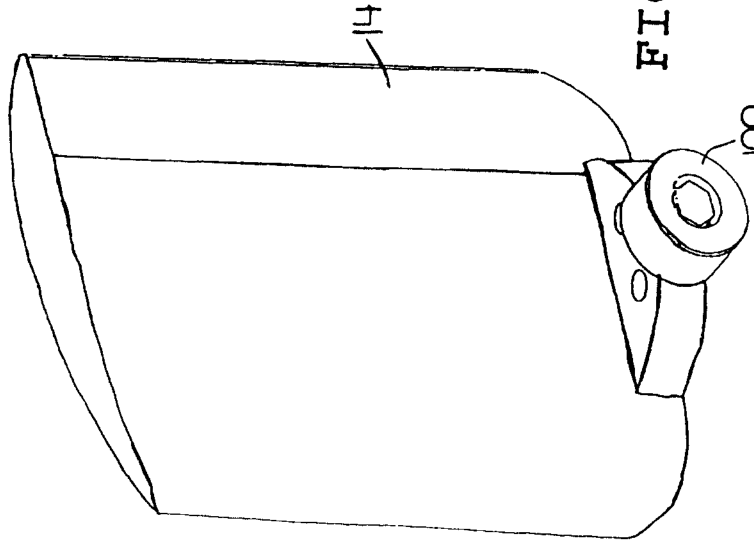

FIGURE 6

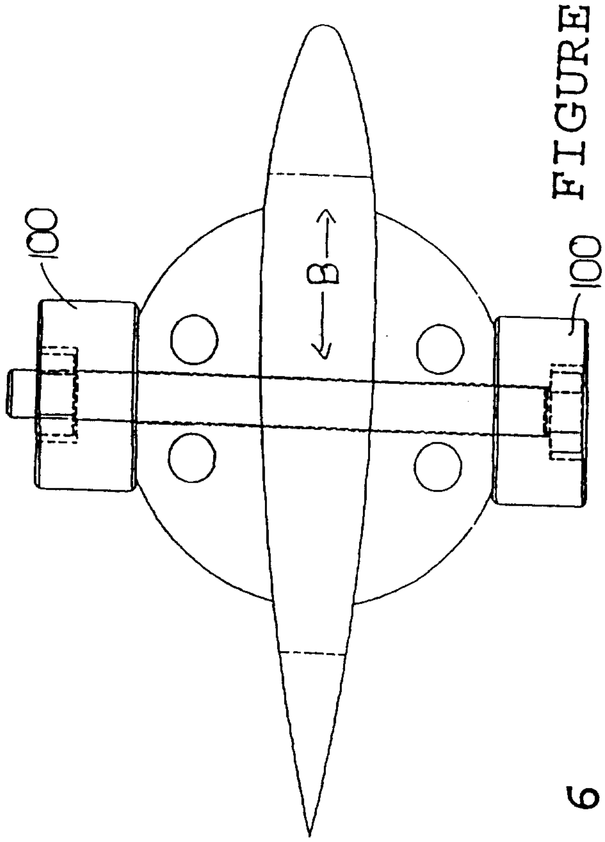

FIGURE 7

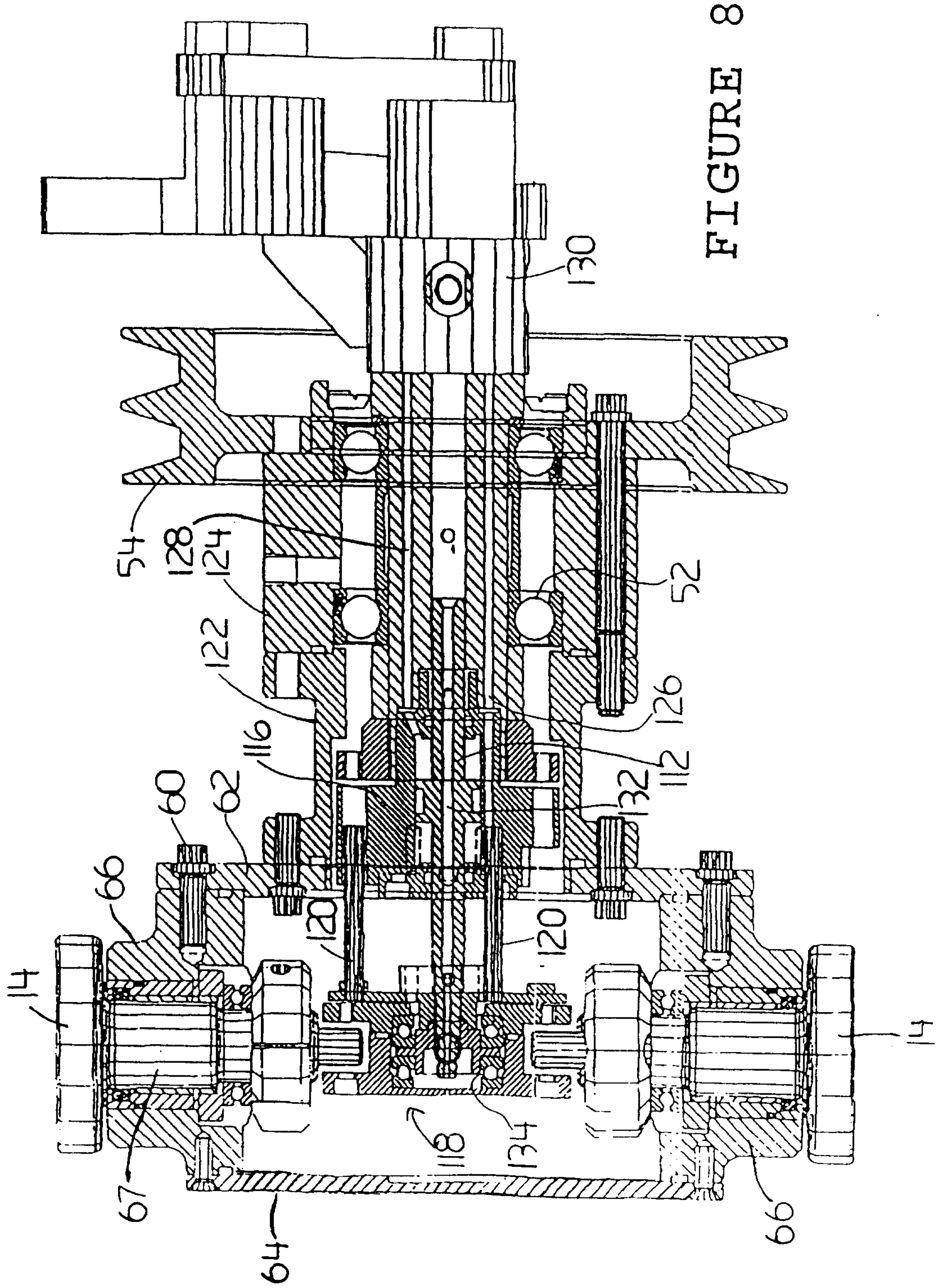
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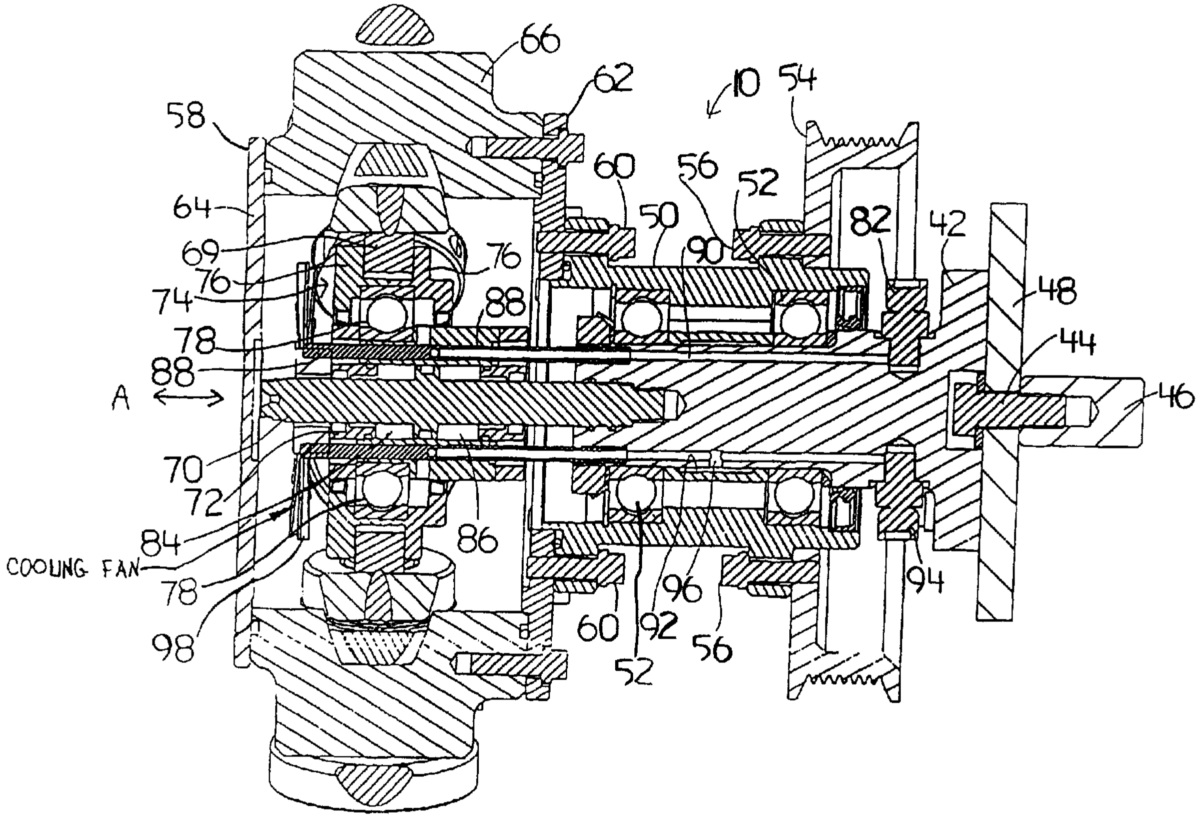
FIGURE 8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