

- [54] **GEAR ARRANGEMENT FOR VARIABLE PITCH FAN**
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- [73] Assignee: **General Electric Company**, Lynn, Mass.
- [22] Filed: **Dec. 21, 1973**
- [21] Appl. No.: **427,377**
- [52] **U.S. Cl.** **416/160**
- [51] **Int. Cl.** **B63h 3/06**
- [58] **Field of Search** 416/160;
74/416-417, 393

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Primary Examiner—Everette A. Powell, Jr.
Attorney, Agent, or Firm—Derek P. Lawrence

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[57] **ABSTRACT**
A variable pitch fan having a plurality of circumferentially spaced apart variable pitch fan blades journalled for rotation about their longitudinal axes in a hub member, further includes a plurality of sector gears drivably connected to the rotor blades and simultaneously actuated by a unison bevel gear wherein each sector gear operates to apply its highest torque to the blades during the cruise mode of engine operation when the inherent turning moments from the centrifugal forces operating on the blades are at their peak.

7 Claims, 6 Drawing Figures

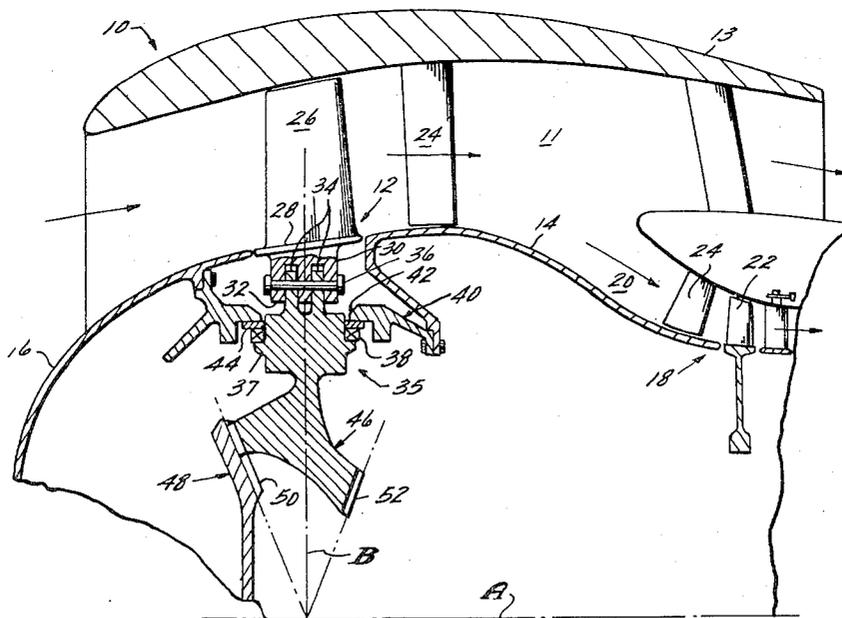


Fig 1

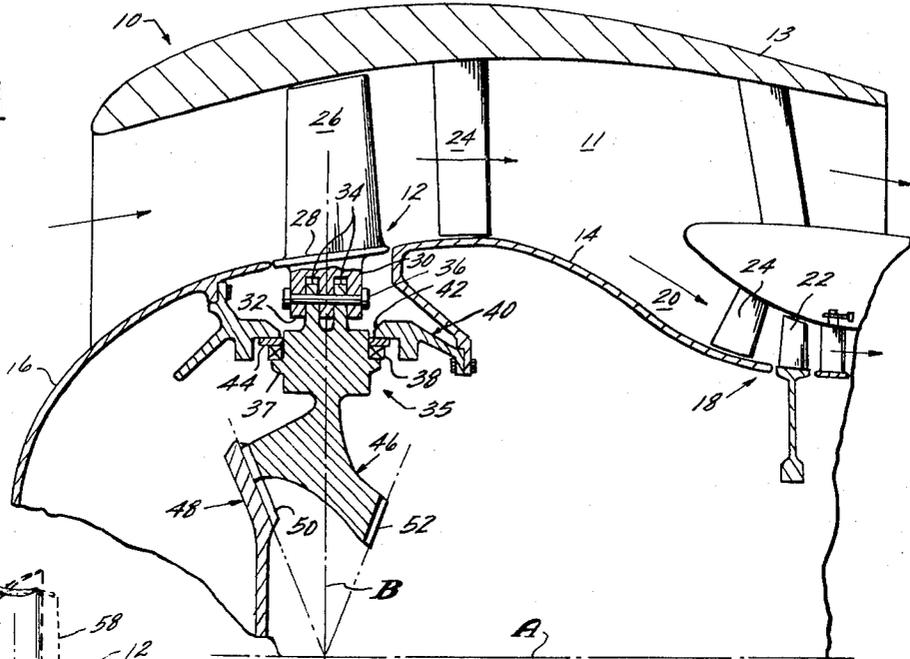


Fig 2

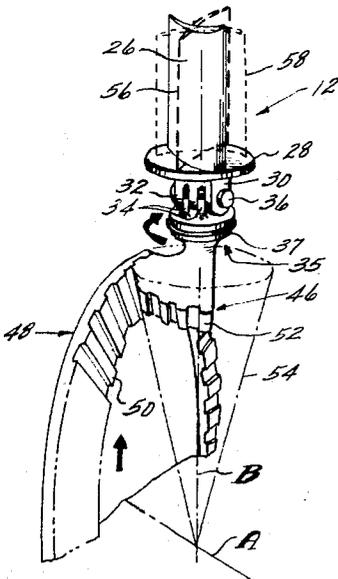


Fig 3

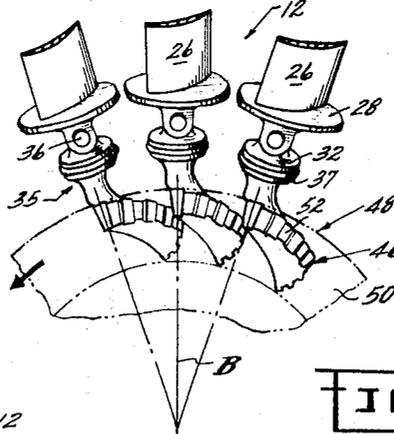


Fig 6

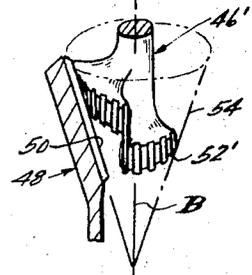


Fig 4

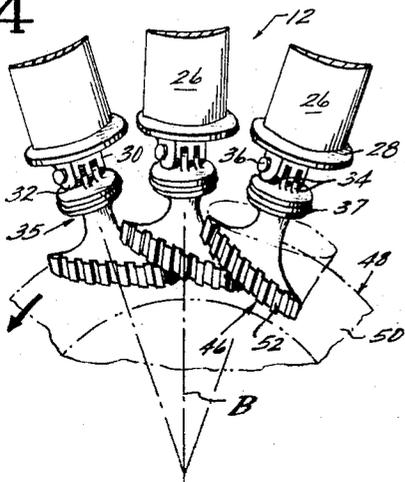
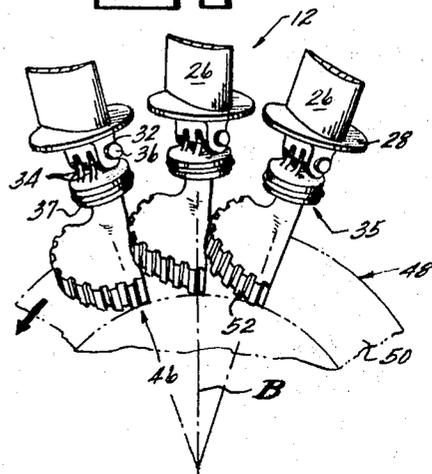


Fig 5



GEAR ARRANGEMENT FOR VARIABLE PITCH FAN

BACKGROUND OF THE INVENTION

This arrangement relates to a gear arrangement for a variable pitch fan and, more particularly, to sector gear arrangement for simultaneously varying the pitch of a plurality of spaced apart variable pitch fan blades journalled in a hub member.

During normal operation of a variable pitch fan, the individual fan blades incur a high dynamic turning moment due to the high centrifugal forces which operate to rotate the blades about their longitudinal center axes such that the major surfaces of each airfoil vane tend to become aligned normal to the center axis of rotation and thus block the airflow through the fan blades. Additional information regarding the inherent turning moments of variable pitch fan blades may be found in U.S. Pat. No. 2,844,303 dated July 22, 1958.

As is well known in the art, the inherent turning moments incurred by variable pitch fan blades must be countered by an opposing force which may be provided by counterbalance weights. Various schemes for such counterbalance weights have been proposed and are well known in the patent literature. However, the inclusion of any type of scheme for counterbalance weights within a rotating fan substantially increases the weight of the rotating components, thus reducing the overall efficiency of the fan. In the gas turbine art where variable pitch fan engines have been recently proposed, such increased weight is unsatisfactory and detracts from the overall efficiency of the engine.

In a variable pitch fan where the individual fan blades have inwardly extending root portions journalled about a central hub member, it is common practice to provide individual sector gears drivably engaged to the blade roots for simultaneously varying blade pitch. The individual sector gears are in turn engaged by a driving unison gear. Increasing the size of the individual sector gears can operate to increase the effective actuating torque applied to the blades and hence counterbalance the inherent turning moments operating on the individual fan blades. However, the size of the sector gears has heretofore been limited by the spacing between adjacent blades and thus failed to provide the adequate actuating torque and/or angles of rotation required to counterbalance the inherent turning moments.

Therefore, it is a primary object of this invention to provide a sector gear arrangement for a turbofan engine through which a high actuating torque may be applied to variable pitch fan blades during the cruising mode of operation where the inherent turning moment is greatest, thus eliminating the need for balance counterweights.

It is also an object of this invention to provide a sector gear arrangement for a variable pitch turbofan engine wherein the teeth of adjacent sector gears overlap in a non-interfering manner so as to provide the high actuating torque required to counterbalance the inherent turning moment together with the necessary angles of rotation.

SUMMARY OF THE INVENTION

These and other objects and advantages will be more clearly understood from the following detailed description and drawings, all of which are intended to be representative of, rather than in any way limiting on, the

scope of invention. The gear arrangement of this invention is provided for a turbomachine of the type having a plurality of spaced apart variable pitch blades journalled in a rotatable hub member. The gear arrangement includes a plurality of spaced apart sector gears in respective driving engagement with the blades wherein each gear has a plurality of teeth spaced apart at varying distances along the length of a conical surface of revolution. There is also provided a unison bevel gear also having a plurality of circumferentially spaced apart teeth for simultaneously engaging the teeth of the sector gears.

DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims distinctly claiming and particularly pointing out the invention described herein, it is believed that the invention will be more readily understood by reference to the discussion below and the accompanying drawings in which:

FIG. 1 is a partial cross-sectional view of the gear arrangement and variable pitch fan of this invention.

FIG. 2 is a partial perspective view of the gear arrangement and variable pitch fan of FIG. 1.

FIG. 3 is a partial perspective view of the cruise mode of operation for the gear arrangement and variable pitch fan of FIG. 1.

FIG. 4 is a partial perspective view of the transition mode of operation for the gear arrangement and variable pitch fan of FIG. 1.

FIG. 5 is a partial perspective view of the reverse mode of operation for the gear arrangement and variable pitch fan of FIG. 1.

FIG. 6 is a partial perspective view of an alternate embodiment of the gear arrangement and variable pitch fan of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown an arrangement for a variable pitch fan 10 which is suitable for attachment to the forward end of a gas turbine engine (not shown). Although the invention is herein described in relation to a variable pitch fan, it will be readily understood to have broader application to other types of axial flow turbomachinery wherein blades are journalled in a rotatable hub member with each blade being adjustably rotatable along its longitudinal axis. The variable pitch fan 10 includes a plurality of circumferentially spaced apart variable pitch fan blades 12 disposed about an inner fairing 14 which extends forwardly of the variable pitch blades 12 and defines an upstream spinner 16. A static bypass duct 11 is provided between the inner fairing 14 and an outer spaced apart cowling 13.

The gas turbine engine may be of a conventional type having a compressor section, a combustion section (not shown), and a turbine section (not shown) arranged in serial flow relation on either a single shaft or a dual shaft (not shown). The variable pitch fan blades 12, together with the inner fairing 14 and the spinner 16, are all interconnected for rotation about a longitudinal engine center axis A by a rotating frame structure (also not shown) as is well known in the gas turbine art. The outline of only the forward end of the compressor is illustrated at 18 and defines a compressor inlet 20 communicating with a plurality of rotatable compressor

blades 22 interspaced between a plurality of stator vanes 24 which may be of the variable type. The compressor is thus charged by a portion of the airflow emanating from the fan 10 and the variation of blade pitch not only varies bypass ratio but in effect provides a variable first compressor stage. A plurality of circumferentially spaced apart stator vanes 24 may be mounted between the inner fairing 14 and the outer cowling 13 aft of the variable pitch fan blading 12 and ahead of the compressor inlet 20. The pitch of the fan blading 12 may be varied to reverse the airflow along the duct 11 and thus provide reverse thrust to aerodynamically brake a landing aircraft.

Each variable pitch fan blade 12 includes an airfoil vane portion 26 extending radially outward from a platform 28 which overhangs an inwardly directed root section 30. Each root section 30 preferably includes a plurality of radially inwardly directed, spaced apart, tangs 32 which are maintained in pinned interspaced relation with a second plurality of tangs 34 extending radially outward from a root shaft 35. The interspaced tangs 32 and 34 are maintained in pinned relation by a longitudinally extending pin 36 which extends through a plurality of coaxially spaced apart holes in the tangs 32, 34.

The pinning of variable pitch fan blades has been found to be advantageous from a vibrational point of view and such pinned blades appear to survive under conditions which would ordinarily promote the rapid failure of fixed root blades. In addition, pinning variable pitch fan blades provides an easy means for removing and replacing the fan blades. It should also be appreciated that small clearances may be provided between the pin receiving holes and the pins 36 so as to permit some rigid body motion through the rolling or slipping together of contacting surfaces. Also, by changing the pin clearances, considerable control may be had over the resonant characteristics without having to redesign the airfoil vane section 26. Although the variable pitch fan blades have been described in a preferred embodiment with pinned roots, it will be readily apparent that the variable pitch fan blades could also be retained by conventional dovetail roots.

The root shaft 35 of each variable pitch fan blade 12 is thickened at its inner radial end to form a circumferential flange 37 which engages a plurality of circumferentially spaced apart anti-friction bearings 38. The rotating structure includes a reinforced cylindrical support or hub section 40 which has a plurality of circumferentially spaced apart radial bores 42 therethrough, each one of which receives a root shaft 35 from a variable pitch fan blade 12. The radial bores 42 each include an overlapping circumferential flange portion 44 aligned in substantially opposing relation to a corresponding circumferential flange 37 so as to maintain the anti-friction bearings 38 therebetween. In this manner, each blade is maintained for rotation about its center axis B at the high centrifugal load forces which are incurred during high speed operation of the fan 10.

Referring now to FIG. 2, in conjunction with FIG. 1, there are shown a plurality of circumferentially spaced apart sector gears 46 extending radially inward from integral connection with the root shafts 35. Each of the sector gears 46 includes a plurality of circumferentially spaced apart teeth 52 extending from the outer periphery thereof for engagement with a second plurality of circumferentially spaced apart teeth 50 disposed

around the periphery of a unison bevel gear 48. During engine and fan operation, the unison bevel gear 48 may be controlled by conventional means to rotate about the longitudinal engine axis A independently of fan rotation. Thus, it will be apparent that a change in the angular position of the unison bevel gear 48 with respect to the support section 40 operates to simultaneously rotate all the spaced apart sector gears 46 about their longitudinal axes B. Rotation of all the sector gears 46 about their longitudinal axes B simultaneously varies the pitch of all the fan blades 12. In this manner, the pressure ratio across the fan blades 12 may be varied to meet the different engine operating requirements as the flight mission dictates.

During fan operation, the individual fan blades 12 incur a high dynamic turning moment due to the high centrifugal forces which operate to rotate the blades about their longitudinal center axes B such that the major surfaces of each airfoil vane 26 tend to become aligned normal to the engine center axis A of fan rotation and thus block the airflow through the static bypass duct 11. For additional information regarding inherent turning moments of variable pitch fan blades, please refer to U.S. Pat. No. 2,844,303 dated July 22, 1958.

As is well known in the art, the inherent turning moments incurred by variable pitch fan blades must be countered by an opposing force which may be provided by counterbalance weights. Various schemes for such counterbalance weights have been proposed and are well known in the patent literature. However, as previously discussed, the inclusion of any type of scheme for counterbalance weights within a rotating fan substantially increases the weight of the rotating components, thus reducing the overall efficiency of the fan.

Increasing the size of the individual sector gears can also operate to increase the effective actuating torque applied to the blades and hence counterbalance the inherent turning moments operating on the individual variable pitch fan blades. However, the size of the sector gears has heretofore been limited by the spacing between adjacent blades and thus failed to provide the adequate actuating torque required to counterbalance the inherent turning moments.

The individual sector gears of this invention, however, have been specially designed to provide a high actuating torque at the normal cruise position of the variable pitch fan blades where the inherent turning moment is greatest, thus eliminating the need for any type of counterbalance weights. Referring now especially to FIG. 2, it can be seen that the teeth 52 of the sector gear 46 evolve in a spiraling helix about a conical surface of revolution shown generally by the phantom line 54 around the blade longitudinal axis B. The teeth 52 are of shorter longitudinal length than the teeth 50 of the unison bevel gear 48 and thus engage the bevel gear at varying radial distances from the engine center axis A with changes in blade pitch. In the preferred embodiment herein depicted, it is not necessary that the teeth 52 evolve a full 360° about the conical surface 54 in view of the limited range of variation of blade pitch required for normal engine operation. However, for other applications it would be possible to evolve the teeth 52 through a full 360° or more depending upon the amount of variation in blade pitch desired.

Referring now to FIG. 3 in conjunction with the solid line airfoil vane 26 of FIG. 2, there is shown the cruise

position for the variable pitch fan blades 12 wherein the inherent turning moments due to the high centrifugal forces operating on the blades are at their peak. It will be readily appreciated that the teeth 52 which are engaged with the teeth 50 of the unison bevel gear 48 during the cruise position are at the outer end of the helical spiral, and hence apply the greatest turning moment to the root shaft 35 due to their increased diametral distance from the longitudinal blade axis B. Despite the increased diametral distance of the teeth 52 engaged with the teeth 50 of the unison bevel gear 48, there can be seen to be no interference between the non-engaged teeth 52 of adjacent sector gears 46. As is readily apparent, the angle at which the teeth 50 of the unison bevel gear 48 would intersect the engine center axis A must coincide with the angle at which the conical surface of revolution 54 intersects the engine center axis A. The teeth 50 and 52 may be straight, tapered, or angled, depending upon the configuration desired.

Turning now to FIG. 4, in conjunction with the phantom line airfoil vane section 56 of FIG. 2, there is shown the position assumed by the variable pitch fan blades 12 at the instant of transition from a forward mode of propulsion to a reverse mode of propulsion. The individual sector gears 46 have been rotated in a clockwise direction as viewed from the top of the variable pitch fan blades 12 and the teeth 52 engaged by the teeth 50 of the bevel gear 48 have moved radially and diametrically inward along the conical surface of revolution indicated by the phantom line 54. It should be readily understood that the clockwise direction of rotation has only been arbitrarily established for purposes of illustration and that a counterclockwise direction of rotation would be equally suited for purposes of this invention. The magnitude of the torque applied to the sector gears 46 by the bevel gear 48 has also correspondingly decreased due to the shortening of the effective moment arms between the bevel gear and the blade longitudinal axis B. The major surfaces of the airfoil vanes 26 are also aligned normal to the engine center axis A (flat pitch) and hence the effects of the inherent turning moments which normally operate to rotate the blades about their longitudinal center axis B is negligible. Referring particularly to FIG. 4, it can be seen that the outer ends of the teeth 52 which initially engaged the unison bevel gear 48 during the cruise position do not interfere with the adjacent sector gears during blade rotation, but instead overlap the adjacent sector gears in a non-interfering manner.

Referring now to FIG. 5, in conjunction with the phantom line airfoil vane section 58 of FIG. 2, there is shown the position assumed by the variable pitch fan blades 12 during the reverse thrust mode of operation when the direction of airflow through the bypass duct 11 is reversed. The teeth 52 which engage the teeth 50 of the unison bevel gear 48 have been rotated to their radial and diametral inner limit while the non-engaged portions of the teeth 52 overlap adjacent sector gears 46 in a non-interfering manner. The torque applied to the sector gears 52 is at its minimum which is entirely satisfactory due to the reduction in the inherent dynamic turning moment which operates on the blades during reverse pitch.

Accordingly, while a preferred embodiment of the present invention has been depicted and described, it will be appreciated by those skilled in the art that many

modifications, substitutions and changes may be made thereto without departing from the invention's fundamental theme. For example, although the teeth 52 are arranged in spaced apart relation along a helical spiral, it will be readily appreciated that the teeth 52 may also be spaced apart in any manner along the length of the conical surface of revolution 54 so long as the teeth of the bevel gear 48 are sufficiently long to engage all the teeth of the sector gear. Thus, there may be a discrete jump from one tooth of the sector gear to an adjacent tooth as shown in the alternate embodiment of FIG. 6, where a sector gear 46' includes two distinct tiers of teeth 52' for engagement with the unison bevel gear 48. Thus having described preferred embodiments of the invention, though not exhaustive of all possible equivalents, what is desired to be secured by Letters Patent is distinctly claimed and particularly pointed out in the claims appearing below.

What is claimed is:

1. In a turbomachine of the type having plurality of spaced apart variable pitch blades, journaled in a rotatable hub member, a gear arrangement comprising:

a plurality of spaced apart sector gears in respective driving engagement with the blades wherein each gear has a plurality of teeth spaced apart at varying distances along the length of a conical surface of revolution,

said sector gears arranged such that the spaced apart teeth of any two adjacent gears overlap without engaging each other, and

a unison bevel gear having a plurality of circumferentially spaced apart teeth in simultaneous driving engagement with the teeth of the sector gears.

2. The turbomachine of claim 1 wherein the angle at which the conical surface of revolution intersects the center axis of hub rotation coincides with the angle at which the teeth of the unison bevel gear would intersect the center axis of rotation.

3. The turbomachine of claim 2 wherein the teeth of the sector gears evolve in a spiraling helix and are of shorter longitudinal length than the teeth of the unison bevel gear and thus engage the bevel gear at varying radial distances from the center axis of rotation with changes in blade pitch.

4. In a gas turbine engine having a variable pitch fan with a plurality of circumferentially spaced apart variable pitch fan blades, each of which includes an airfoil vane portion together with a root journaled about an inner hub member for rotatable adjustment, an actuating gear arrangement comprising:

a plurality of circumferentially spaced apart sector gears in respective driving engagement with the blade roots wherein each gear has a plurality of teeth spaced apart at varying distances along the length of a conical surface of revolution,

said sector gears arranged such that the spaced apart teeth of any two adjacent gears overlap without engaging each other, and

a unison bevel gear disposed for rotation about the longitudinal engine center axis and having a plurality of circumferentially spaced apart teeth disposed about the outer periphery thereof for simultaneous driving engagement with the teeth of the sector gears.

5. The gear arrangement of claim 4 wherein the angle at which the conical surface of revolution intersects the longitudinal engine center axis coincides with the angle

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at which the teeth of the unison bevel gear would intersect the engine center axis.

6. The gear arrangement of claim 5 wherein the teeth of the sector gears evolve in a spiraling helix and are of shorter longitudinal length than the teeth of the unison bevel gear and thus engage the bevel gear at varying radial distances from the center axis of the engine with changes in blade pitch.

7. The gear arrangement of claim 6 wherein: the teeth of each sector gear which engage the teeth of the unison gear are at the outer end of the helical spiral during the cruise mode of engine operation so as to apply the greatest torque to the blade roots

when the inherent turning moments from the high centrifugal forces operating on the blades are at their peak; and variation in blade pitch toward flat pitch and reverse pitch operates to move the engaging teeth of each sector gear radially and diametrically inward along the conical surface of revolution such that the outer ends of the teeth of the sector gears which engage the unison bevel gear during the cruise position do not interfere with adjacent sector gears, but instead overlap the adjacent sector gears in a non-interfering manner.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,870,434

DATED : March 11, 1975

INVENTOR(S) : Elmir Edward Paulson

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, Claim 3, line 42, the word "gevel" should read --bevel--.

Signed and sealed this 20th day of May 1975.

(SEAL)

Attest:

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Attesting Officer

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Commissioner of Patents
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