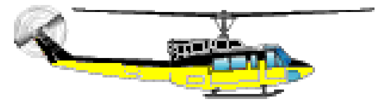

CHAPTER 9

MAIN ROTOR SYSTEM

TABLE OF CONTENTS

ILLUSTRATIONS

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MAIN ROTOR SYSTEM

INTRODUCTION

The main rotor assembly is a two bladed, semi-rigid type. The rotor assembly is pre-coned and has an under slung feathering axis. Design of rotor allows flapping (seesaw) and pitch change of individual blades.

GENERAL

The rotor is semi-rigid, which eliminates the possibility of ground resonance because of rigidity of the blade hub unit.

The under slinging of the rotor hub yoke (Figure 9-1) on its mounting trunnion keeps the center of mass in the same place eliminating the need for drag hinges. Hunting is absorbed through blade bending. The yokes are pre-coned to relieve strain on the yoke with rotor coning, and the high kinetic energy main rotor blades allow for safe easy to perform auto rotational landings in the event of a dual engine failure. Also a stabilizer bar is attached to the main rotor system in such a way as to provide stability for all flight conditions through the gyroscopic action and inherent inertia of the bar. The Bell 212's two bladed rotors allows for a smaller space in the hanger with no blade folding necessary.

MOUNTING

The main rotor hub and blades are mounted to the upper splines of the mast in the following manner (Figure 9-2). The splines on the rotor hub trunnion are aligned with the upper splines of the mast. The rotor hub is lowered and seated onto a split cone set placed in a groove of the upper spline. The beveled side of the split cone, wedged against the hub, holds the assembly up when the rotor is static. The assembly is then secured to the mast by a retaining nut that is threaded onto the top of the mast.

PERTINENT DATA

- Rotor Diameter 48 feet
- Hub Weight 333 pounds
- Blade Weight/Pair 450 pounds
- Blade Chord 21.00/23.38 inches
- Total Flapping 22 degrees
- Low Pitch Angle 8 plus/minus ½°
- Rotor Flight Limitations as follows:
- Minimum - 91% rotor RPM (294 RPM) power OFF
- Minimum - 97% rotor RPM (314 RPM) power ON
- Maximum - 100% rotor RPM (324 RPM) power ON
- Maximum - 104.5% rotor RPM (339 RPM) power OFF
- Rotor RPM Light

  RPM light should illuminate and a varying audio tone in the pilot and co-pilot headsets at 92.6% ± 2% rotor RPM. The RPM light should illuminate at 103% ± 2% rotor RPM, without an audio tone in the pilot and co-pilot headsets.

ROTOR BLADE MOVEMENTS

BLADE PITCH CHANGE OR FEATHERING

Blade pitch change is accomplished by the rotation of the blades about their span wise axis. Each main rotor blade is mounted to a blade grip by means of a retaining bolt in the grip, and the blade grips rotate around the spindles on the yoke to change the blade pitch. Bearings mounted between each blade grip and yoke spindle allow for this rotation and are lubricated by the two blade grip reservoirs. The TT Straps twist, allowing the grip to rotate around the spindles.

BLADE FLAPPING

Blade flapping is necessary to compensate for dissymmetry of lift. As the advancing blade flaps up due to increased lift, the retreating blade flaps down due to decreased lift. Since the angle of attack changes on each blade because of this flapping action, the lift over the rotor disc halves tends to equalize. The blades are rigidly connected to the hub, allowing the blades to flap as a unit, and the hub is free to teeter with respect to the rotor mast through the trunnion.

MAIN ROTOR HUB

The main rotor hub is composed of a yoke, two pillow blocks, a trunnion, two blade grips, two retention straps, two pitch horns, and two drag braces (Figure 9-3).

YOKE

The yoke is made from forged steel and has two spindles 180° apart. The spindles are hollow to house the retention straps and are threaded on the end to receive the bearing retainer nut. Holes are provided near the center. The spindles are pre-coned 2 1/2 to 3 degrees to relieve the bending load on the yoke due to coning of the rotor section for mounting the pillow blocks. Stop assembly mounted on lower side positions a radius ring and limits rotor flapping by contacting mast

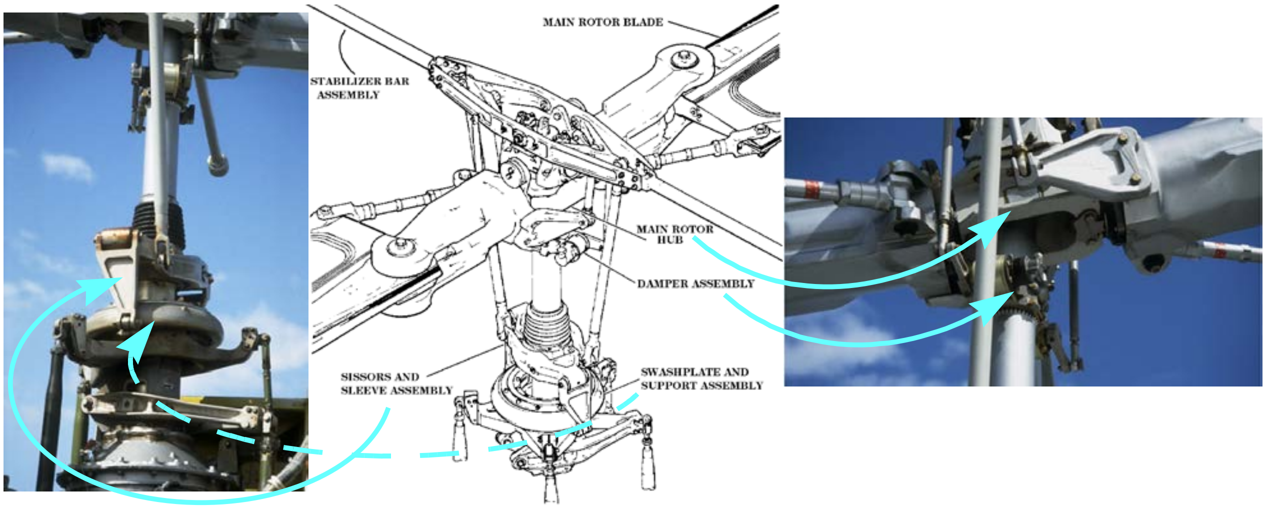

Figure 9-1 Main Rotor System

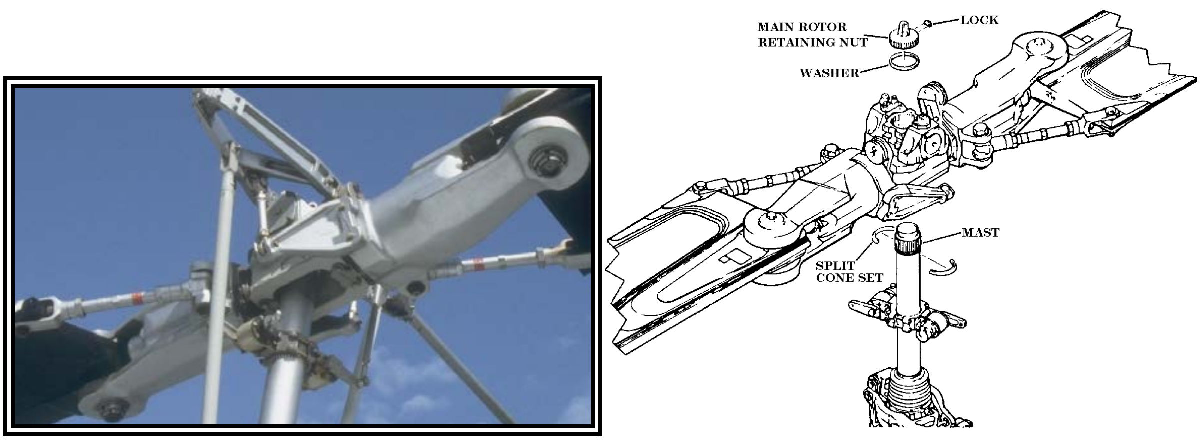

Figure 9-2 Rotor Hub Mounting

PILLOW BLOCKS

Two aluminum pillow blocks serve to mount yoke to the trunnion, thus providing a flapping axis for the rotor. Each pillow block is mounted to the yoke with two bolts through bushings. The trunnion provides the flapping axis for the rotor and provides a means of mounting the rotor assembly to the mast.

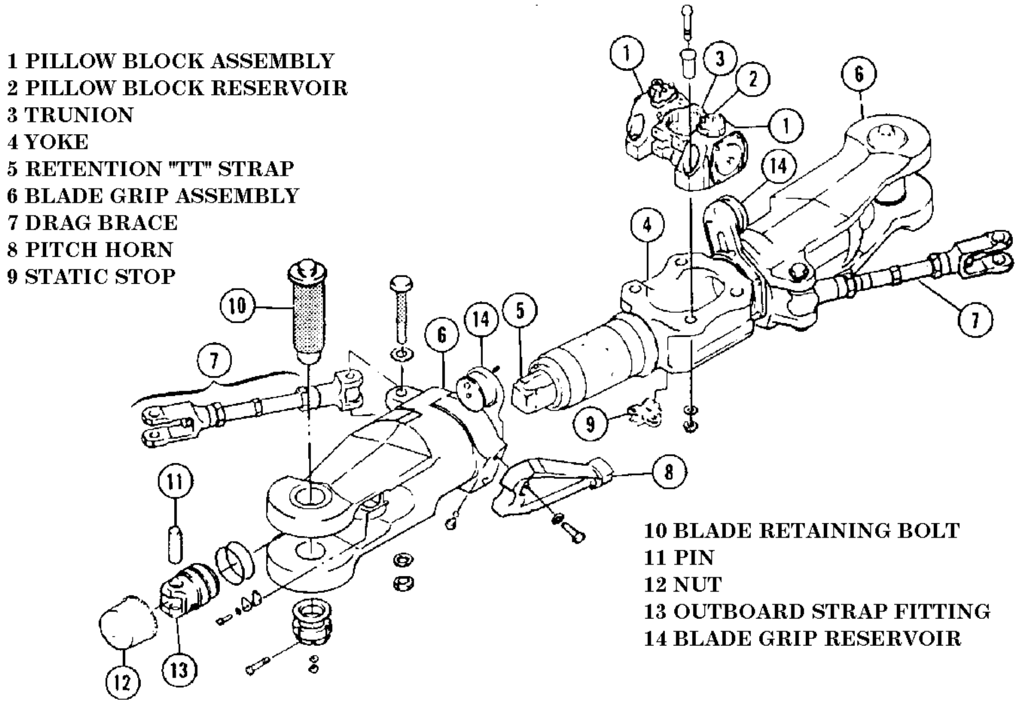

Figure 9-3 Main Rotor Hub Diagram

TRUNNION

The stainless steel trunnion provides the means of mounting the rotor assembly to the mast. It also provides the flapping axis for the rotor system through the spindles of the trunnion, which rotates within the pillow blocks.

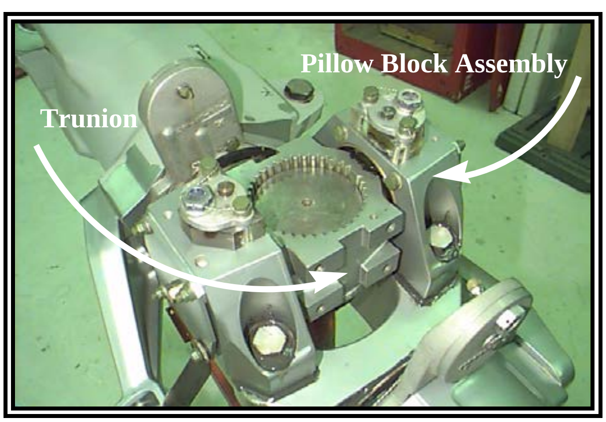

Figure 9-4 Pillow Block

BLADE GRIPS

There are two aluminum blade grips that mount the two main rotor blades onto the hub assembly by use of the blade retaining bolts. Each blade grip is mounted around a yoke spindle by two sets of bearings and held in place by a retention strap. The rotation of the blade grips around the yoke spindles allows the blades to change pitch. There is an oil reservoir to provide lubrication for the bearings and spindle within each blade grip. The reservoirs have sight glasses and utilize engine oil, but a grease fitting modification is available, in which case the reservoirs and sight glasses are not installed.

RETENTION STRAPS

The two retention, or “TT” straps, fit inside the yoke spindles and are attached to the inboard side of each spindle with a fitting. The straps' outboard end is attached to the blade grip through another fitting. In this way the retention straps retain the blade grips and rotor blades to the hub. The retention straps also transmit the thrust, or centrifugal force, from the blade grips to the yoke. Each retention strap consists of 16,000 wraps of .0058/.0062 steel wire around the two steel fittings, and then covered with polyurethane plastic (Figure 9-6).

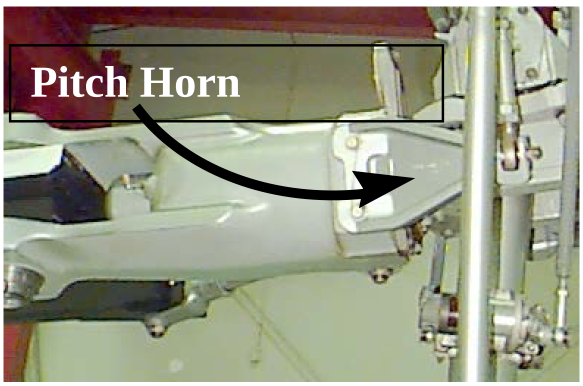

Figure 9-5 Pitch Horns

PITCH HORNS

The aluminum pitch horns are bolted to the leading side of each blade grip and are connected by pitch links to the stabilizer bar mixing levers. The movement of the pitch links up and down pushes the pitch horns that rotate the blade grips, resulting in main rotor blade pitch changes.

DRAG BRACES

The drag braces connect the trailing edge of the main rotor blades to the blade grips and hold the blades in alignment. The barrel of the drag brace is adjustable to allow for sweeping of the main rotor blades for chord wise balancing in the event of a lateral vibration.

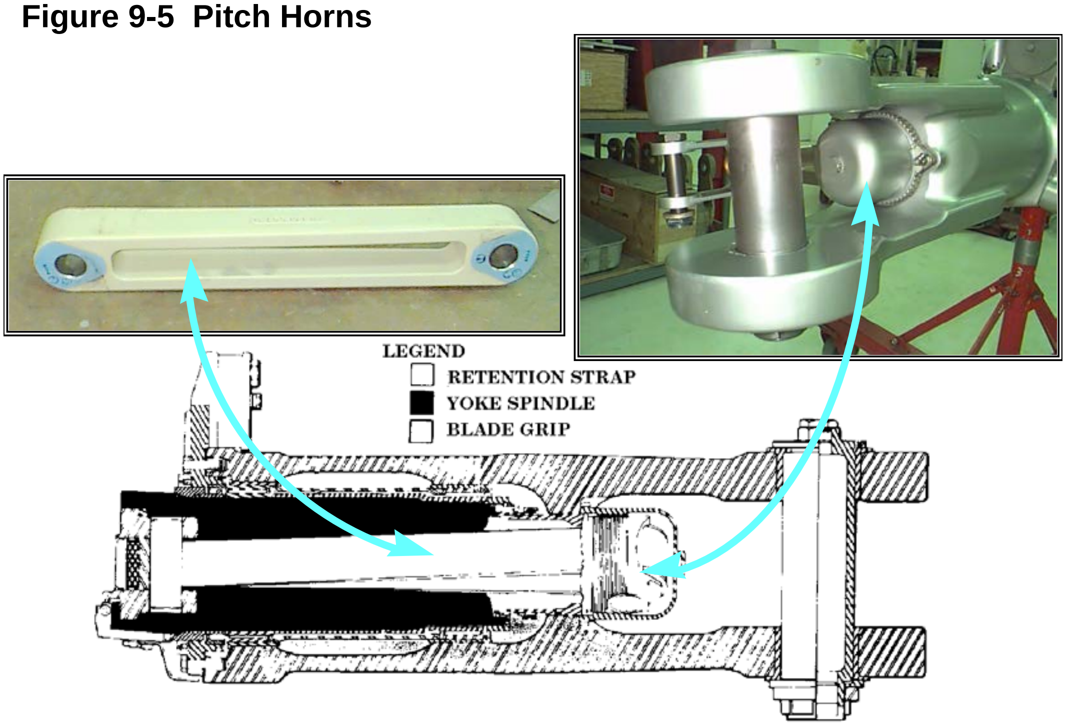

Figure 9-6 Retention Strap and Blade Grip Cross Section

MAIN ROTOR BLADES

The blades are asymmetrical all metal bonded (Figure 9-7) assemblies secured by a steel retaining bolt at each grip and connected by one bolt at each drag brace. Each blade is a thin tip blade, tapering from a 12% airfoil at the 80% rotor radius to a 6% airfoil at the tip (outboard 58 inches). Each blade is constructed of the following parts:

SPAR

The spar is made of "D" shaped aluminum extrusion. Outboard 58 inches split at lead and trailing side of spar to permit taper. Split section mates to zinc alloy nose block at lead side and aluminum spar closure at trailing side. The spar has a fiberglass strip running inside of it.

Box Beam and Spar Doublers

Six doublers bonded to spar, three on top, three on bottom. Inboard and outboard doublers are made of stainless steel and center doublers of aluminum.

Nose Blocks and Spar Closure

Three nose blocks are bonded to lead side of spar. Inboard is of aluminum, center of brass and outboard of zinc alloy. Extruded aluminum alloy closure bonded into split in aft side of outboard 58 inches spar.

Abrasive Strips

Stainless steel abrasive strips are bonded to nose block and spar form leading edge of blade.

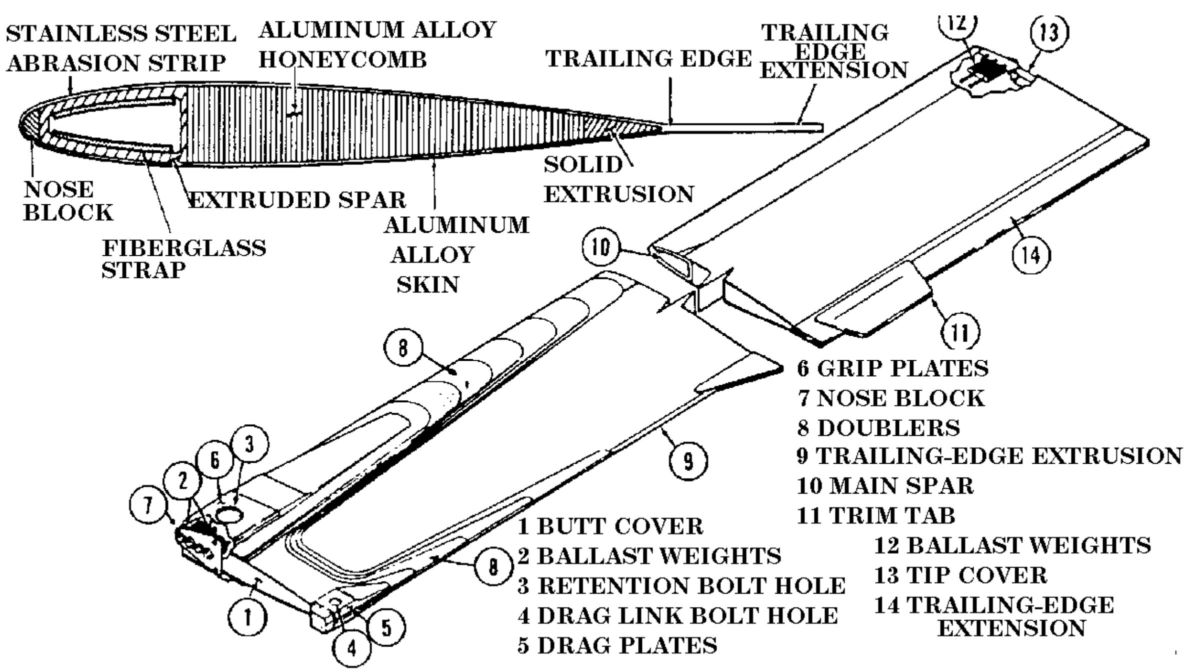

Figure 9-7 Main Rotor Blade

Skins

Upper and lower skin extends from butt to tip. The skin is made from .016 inch thick 2024 aluminum alloy sheets. Skins are bonded to box beams and spar doublers, core and tailing edge strip.

Core

The core consists of two sections of aluminum honeycomb core bonded between skins from spar to trailing edge strip.

Trailing Edge Strip

Extruded aluminum strips bonded between trailing edges of skins for full span of blades.

Doublers

Seven aluminum reinforcing doublers bonded at both upper and lower surface at root end of blade. Four of these doublers extend to trailing edge of blade.

Grip Plate

Upper and lower aluminum grip plates bonded to doublers at blade root.

Grip Pads

Upper and lower steel grip pads bonded to doublers at blade root.

Drag Plates

Upper and lower aluminum drag plates bonded to doublers at blade root. Drag Plates form mounting point for the Drag Brace.

Butt Plate and Cover

Aluminum cover plate is secured by three screws and covers butt end of spar. Balance weights are secured to inside of plate by four bolts. Channel shaped aluminum cover is bonded between skins aft of spar to trailing edge strip.

Tip Cap and Cover

Aluminum cap, secured by two screws to support weight, covers tip of spar and balance weights. Fitting on cap is used for tracking and has hole for rotor tie down. Channel shaped aluminum cover is bonded between skins aft spar to trailing edge strip.

BALANCE WEIGHTS

Internal tip

The internal tip weights are secured by nuts to studs on the aluminum support weight that is bonded and secured by nine countersunk screws to spar.

Internal Spar

Vibration dampening brass weight bonded and secured by 20 bolts to spar. This 20 ± 1/4 pound weight is 20-3/4 inches long and extends inboard from start of blade taper.

Internal Butt

Internal butt weights bolted to butt cover plate inside spar.

External Butt

The external butt weight is attached by three screws to drag plates.

Trim Tab

Aluminum trim tab is bonded to trailing edge extension approximately 30 inches from tip. Tab may be bent to a maximum of 8° using a tab bender and gauge.

STABILIZER BAR ASSEMBLY

The stabilizer bar assembly (Figure 9-8) is attached to the main rotor hub trunnion. The bar is connected into the main rotor system in such a manner that the inherent inertia and gyroscopic action of the bar is induced into the rotor system, providing a measure of stability for all flight conditions.

Hovering

If while hovering, the helicopter is disturbed, the bar, because of its gyroscopic action, tends to remain in its present plane. The relative movement between the bar mast causes the hub and blade assembly to feather and return the rotor to near its original plane of rotation.

Cyclic Control Input

As a result of inducing cyclic control into the main rotor, the angular relationship between the mast and bar will change. Centrifugal force will cause the bar to seek a new plane of rotation perpendicular to the mast, but only after a delay. Over regulated, this delay would result in a loss of stability induced by the stabilizer bar. Conversely, should the bar movement be unregulated, and remain in its original plane or rotation, stability would be induced to the point of removing desirable control from the pilot.

Damper Action

To achieve a balance between stability and desired control response, the rate at which the bar follows the mast must be regulated. Regulation is accomplished by two hydraulic dampers connected to the bar in such a manner that movement of the mast is conveyed by the dampers to position the bar perpendicular to the mast at a predetermined rate.

MAJOR COMPONENTS

Support Assemblies

The aluminum supports provide a pivot point and serve to mount the stabilizer bar to the main rotor trunnion. Four bolts mount each support. Machined surfaces on the support serve as stops for total (30°) stabilizer travel, 15° up and 15° down.

Center Frames

The aluminum center frames form the structure to which the other components are connected. The frames are alike and are attached to the supports through bearings that allow the frames to pivot on the supports. The outer tubes are bolted to the outboard ends of the two center frames. Connecting points are provided for mixing levers and for the damper control tubes that are connected to the leading side of the frames.

Mixing Lever Assemblies

The aluminum mixing levers installed between the center frames serve to mix the pilot's control input with stabilizer bar action. Each mixing lever has three pivot points: center frame attaching points, main rotor pitch link attaching point and scissors control tube attaching point. The mixing levers are alike but must be installed between center frames with their lubrication fittings up.

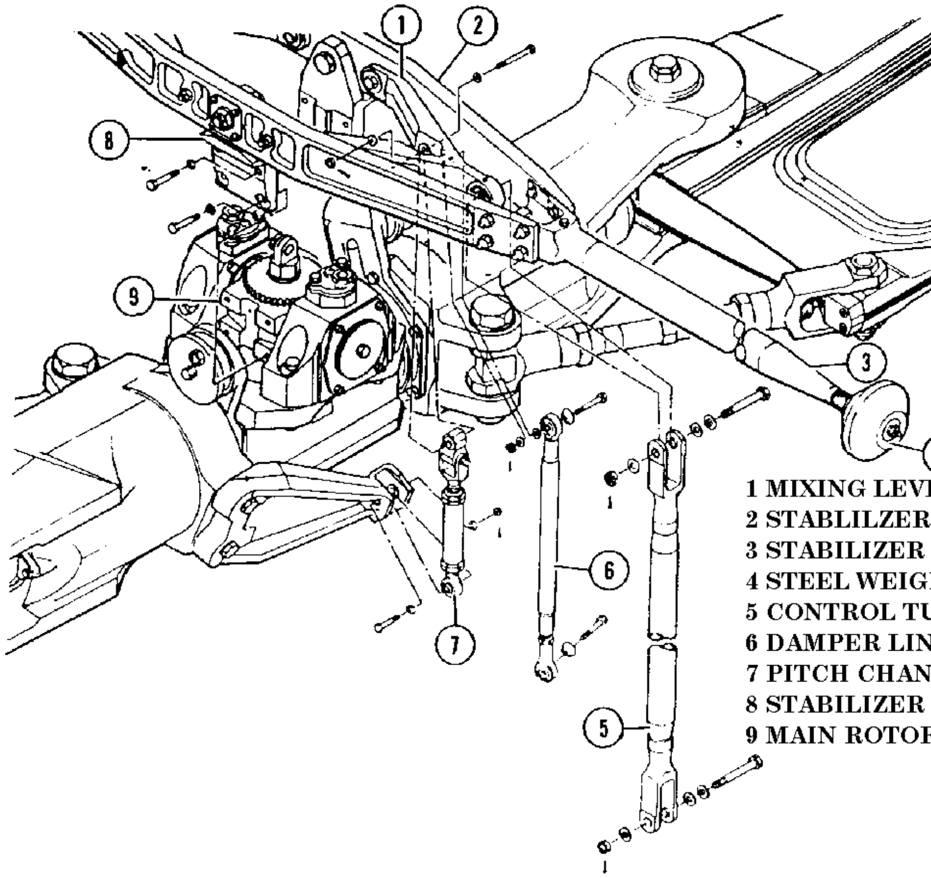

Figure 9-8 Stabilizer Bar Assembly

Outer Tubes

The steel outer tubes bolted to the outboard ends of the center frames support the stabilizer bar weights. Threads are provided at the outboard ends for attaching the weights. The weights are locked to the tubes by check nuts and key type locking devices that are lock wired.

Weights

The steel weights installed to the outboard ends of the outer tubes are alike and each weighs 5.14 pounds.

Cable

The steel cable assembly, which is housed by and attached to the inboard end of the outer tube, serves to retain the weight should the outer tube fail. The inboard end of the cable assembly has a fitting that is bolted to the outer tube. The outboard end of the cable assembly protrudes through the weight and has a threaded fitting to facilitate installation of a washer, rubber bushing, retainer and two nuts. The inner nut insures compression of the bushing and provides a minimum gap of .005" between the retainer and the weight. The outer nut serves as a lock (jam) nut. With this arrangement, the cable assembly does not support the weight during normal flight but would retain it if the outer tube should fail.

DAMPER ASSEMBLY

Two rotary viscous dampers (Figure 9-9A&B) are mounted on a pair of adapters attached to the second set of splines from top of mast. These vane type dampers consist basically of a cylindrical housing with two stationary vanes and a wing shaft. The wing shaft is a shaft with two vanes as an integral part. One end of the wing shaft protrudes through the damper housing and to this end is connected a lever arm which serves as a means of rotating the wing shaft. The four vanes divide the cylinder into four chambers that are completely filled with MIL-L-5606 hydraulic fluid. With any movement of the lever arm the fluid is subjected to forced flow.

As the wing shaft rotates, fluid flows between the four chambers that are interconnected by an orifice in the wing shaft. With this arrangement, a restraining force is developed in the damper that is dependent upon the velocity of fluid flow through the orifice. Slow movement of the lever arm causes low velocity fluid flow through the orifice and consequently little resistance to movement. Rapid movement of the lever arm increases the velocity of fluid flow and thus increases the resistance to motion. Cold fluid moves slower and therefore provides less stability and warm fluid moves faster providing more stability than cold fluid does.

The orifice size determines the speed of movement with which the damper will respond to an applied force. A cam actuated slider valve varies the orifice size. Minimum dampening occurs from the neutral position up to 8 to 10 degrees of damper lever arm travel or approximately 5 degrees results in a greater and proportionately increasing force (smaller orifice**)**.

MAJOR COMPONENTS

Adapter Assembly

The adapter halves, made from a one-piece aluminum casting, serve to mount the dampers to the mast. One half (-5) has a master spline and the other half (-7) does not. Each adapter half is etch marked "TOP" and "BOTTOM" to facilitate proper installation**.**

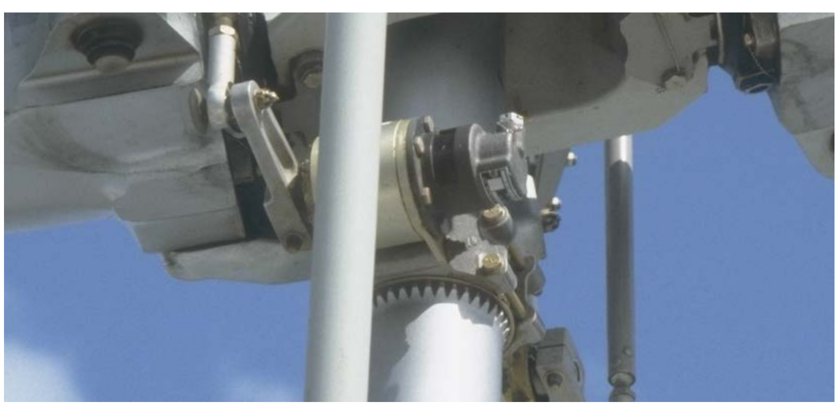

Figure 9-9A Damper Assembly

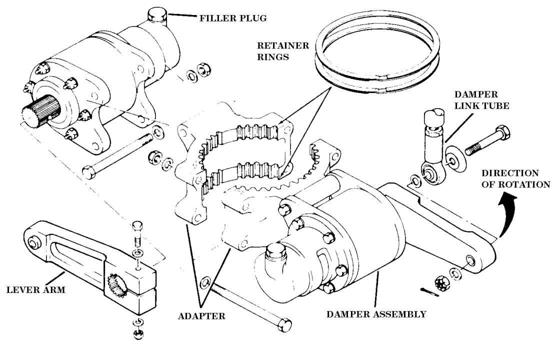

Figure 9-9B Damper Assembly

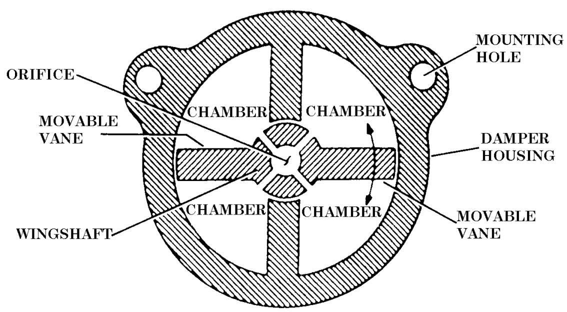

Figure 9-10 Rotary Viscous Damper

Dampers

Each rotary viscous damper is mounted to the adapter assembly, with the wing shaft towards the direction of rotation with two bolts, washers and nuts. A filler plug is provided for occasional addition of MIL-H-5606 hydraulic fluid, as may be necessary due to minor leaks. A window is provided through which an indicator pin and cam mark can be viewed for a check of timing, 5 seconds ± 1 second.

Correct Damper Timing

1. Correct Return of indicator pin
   a. 5 ± 1 Second
2. Resulting in:
   a. Correct stabilizer bar to mast following time
   Stable helicopter
   Correct control response

Hard Damper (cold)

1. Slow return of indicator pin
   a. More than 6 seconds
2. Resulting in:
   a. Quicker stabilizer bar to mast following time
   b. Unstable helicopter
   c. Oversensitive control response

Soft Damper (Bad Seals)

1. Fast return of indicator pin
   a. Less than 4 seconds
2. Resulting in:
   a. Longer stabilizer bar to mast following time
   b. Over stable helicopter
   c. Delayed control response

Lever Arms

An aluminum lever arm is splined to the exposed end of the damper wing shaft. It is held into position on the shaft by a clamp bolt installed through lever arm and grooved area of wing shaft. The damper link tubes from the stabilizer bar are connected to the leading side of the lever arms.

ROTATING CONTROLS

The rotating controls serve the function of converting non-rotating control movement to rotating control movement, thus allowing pitch change control of the main rotor blades when the rotor is turning. This is made possible by the use of two major assemblies, the swash plate and the scissors and sleeve assembly. These two assemblies encircle the mast at the top of the transmission and transmit movements from the cyclic and collective controls in the fuselage to linkage that rotates with the main rotor.

Collective Control

Raising the collective stick will cause the collective scissors and sleeve assembly to move up. The scissors hub, which is connected to the collective sleeve through bearings that allow it to rotate, will also move up. The scissors, attached to the hub, will move with the hub and cause the control tubes connected to the stabilizer bar mixing levers to move up. This will cause the pitch horns that are mounted to leading side of the grips to move up. This results in the grips rotating to increase the pitch of both blades equally and simultaneously. Lowering the collective stick decreases the pitch of both blades equally and simultaneously.

Cyclic Control

Movement of the cyclic control stick results in a corresponding tilt of the swash plate. The swash plate's outer ring rotates with and is connected to the scissors by two drive links. Tilting the swash plate will actuate the short arms of the scissors, one up and one down. The long arm of the scissors will move in the opposite direction. This causes one control tube to move up and the other to move down, resulting in one blade increasing pitch and the other decreasing. When the main rotor is turning, the blades will continuously change pitch as they followed the tilt of the swash plate.

MAJOR COMPONENTS

Collective Scissors and Sleeve Assembly

Located above the transmission and encircles the mast. Collective control movement causes sleeve assembly to move vertically within the swash plate support.

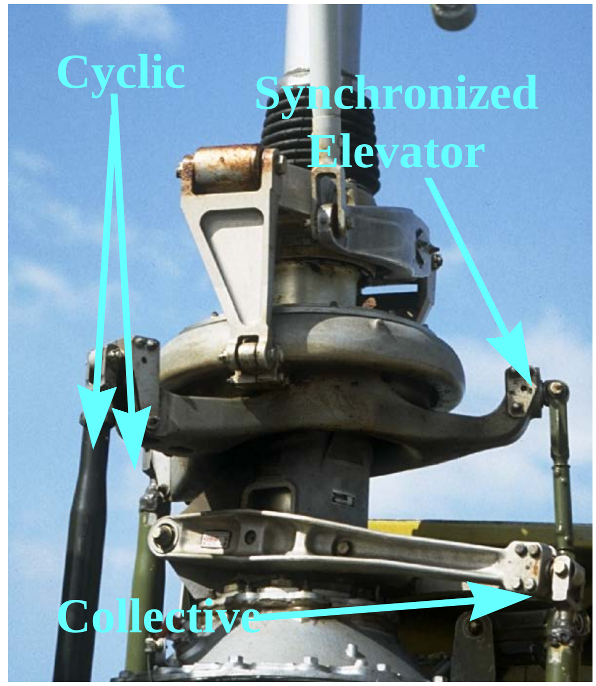

Figure 9-11 Rotating Controls

Collective Sleeve

Made of steel and tubular in shape. Two bosses at the lower end of the sleeve accommodate two ball bearing and linear assemblies, which are attached by four machine screws each. The bearings receive the dowel pins of the collective levers, which actuates the sleeve vertically but prevents the sleeve from rotating. Shims positioned on the lever dowel pins center the collective sleeve within the swashplate support. A set of four angular contact bearings and spacer set are retrained at the top of the sleeve by a left-hand threaded nut.

Hub Assembly

Made of steel and mounted to outer races of bearings. Retained to bearings by a nut threaded into the hub. The hub rotates with the mast and drives the scissors that are attached to and pivot at the hub.

Drive Plate

Made of bronze and bolted to the collective hub assembly. Plate has splines, on its inner diameter that mate with the spline set on the mast. The master spline properly positions the rotating controls to the main rotor and stabilizer bar. The plate slides up and down the mast splines and drives the scissors hub. A flange, used to secure the lower end of a boot, is secured to the plate and hub by the six plate retaining bolts.

Scissors Assembly

Two aluminum scissors assemblies are connected to and allowed to pivot at the scissors hub. The scissors levers, through the drive links, drive the outer ring of the swashplate. In addition, the scissors levers transmit the tilt of the swashplate to the rotor disc for cyclic control movement and the vertical movement of the collective control motion.

Drive Links

Two drive links connect between the two scissors and the trunnions on the swashplate's outer ring. The drive links, driven by the scissors, drive the swash plate's outer ring and transmit cyclic control motion.

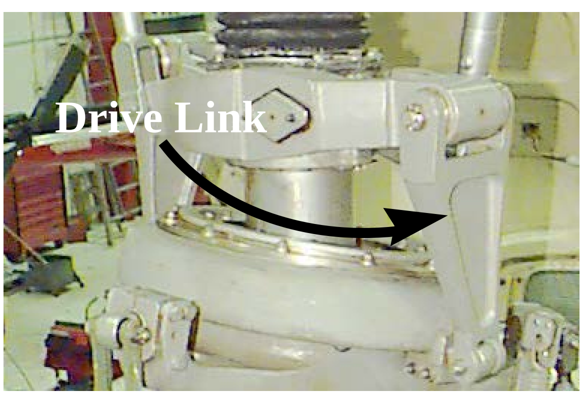

Figure 9-12 Drive Link

Swashplate Assembly

Located above the transmission and encircles the mast and collective sleeve. Cyclic control movement causes swashplate's inner and outer rings to tilt.

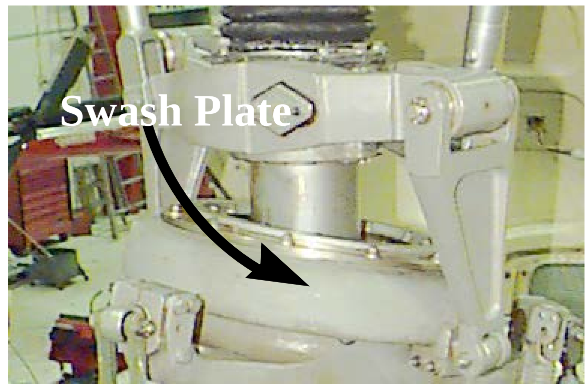

Figure 9-13 Swash Plate

Support Assembly

Aluminum casting of open cylinder design, with a mounting flange at lower end and clevis shaped ears at upper end for attaching the gimbal ring. The support is mounted through the flange to the mast bearing retainer plate with eight steel bolts and aluminum washers. Extended bosses near base of support are used to support the collective levers to the collective sleeve.

Gimbal Ring

Made of steel, the gimbal ring connects the inner to the support and allows inner ring to tilt in any direction.

Inner Ring

Non-rotating component pivot mounted to the gimbal ring. Made of aluminum and has trunnion installed in three horns. Cyclic controls are connected to the two forward horns and when actuated, cause the inner ring to tilt. Aft horn connects to and actuates the elevator control linkage. Safety plates are provided on both sides of each horn, except for right hand horn that has a bracket on the outboard side for a tension spring attachment. The bracket acts as a Safety plate also. Safety plates retain the trunnion in the horn, should the horn crack due to over torqueing of bolts.

Outer Ring

Rotating component mounted to inner ring through a dual thrust bearing. Driven by the two drive links and tilts with the inner ring. Two trunnion bolts to outer ring connect to drive links.

Collective Lever Installation

Installation provides a means of transmitting control motion from the collective servo actuator to the collective sleeve. Installation consists of two levers, trunnion, spacer, shims and attaching bolts, washers and nuts. Each lever has a dowel pin that mates inside a bearing on the lower end of collective sleeve. Forward end has steel liner and bearing for connecting the lever to the washplate support. Levers are bolted together with a spacer and trunnion between them.

MAIN ROTOR RPM WARNING DEVICES

Two warning devices are provided in the Bell 212 to advise the pilot if rotor rpm exceeds limits: the rpm caution lights and the low rpm audio signal or horn (Figure 9-14). Both of these devices are activated by NR tachometer generator signals and the rpm warning and control unit utilizing DC electrical power protected by the ROTOR RPM circuit breaker on the overhead console.

ROTOR RPM CAUTION LIGHTS

An rpm caution light is located at the top of each pilot's instrument panel. The caution light system is activated when DC power is applied to the system and the rpm caution lights illuminate with an audio tone. As rotor rpm increases through 93-95%, the rpm caution lights extinguish.

During normal rotor operation between 97 and 100%, the rotor rpm lights remain off. If rotor rpm drops below 92.5 ± 2 %, the rpm caution lights illuminate, giving the pilots visual indication of low rotor rpm.

The pilot should lower the collective and/or increase the rpm beep switch to increase rotor rpm and extinguish the rpm caution lights. If rotor rpm exceeds 103%, the rpm lights illuminate, indicating high rotor rpm.

LOW ROTOR RPM AUDIO

WARNING SYSTEM

The rotor rpm audio warning operates in conjunction with the rpm caution light except it warns only of low rotor rpm. The system activates when DC power is turned on. The tone ceases as rotor rpm increases through 93-95% and remains off at rotor rpm above 93%.

During normal rotor operation between 97% and 100%, the audio warning tone remains off. If rotor rpm drops below 92.5 ± 2% the audio tone is heard, giving the pilots audible indication of low rotor rpm. The pilot should lower the collective and/or increase the rpm beep switch to increase rotor rpm and stop the audio warning tone.

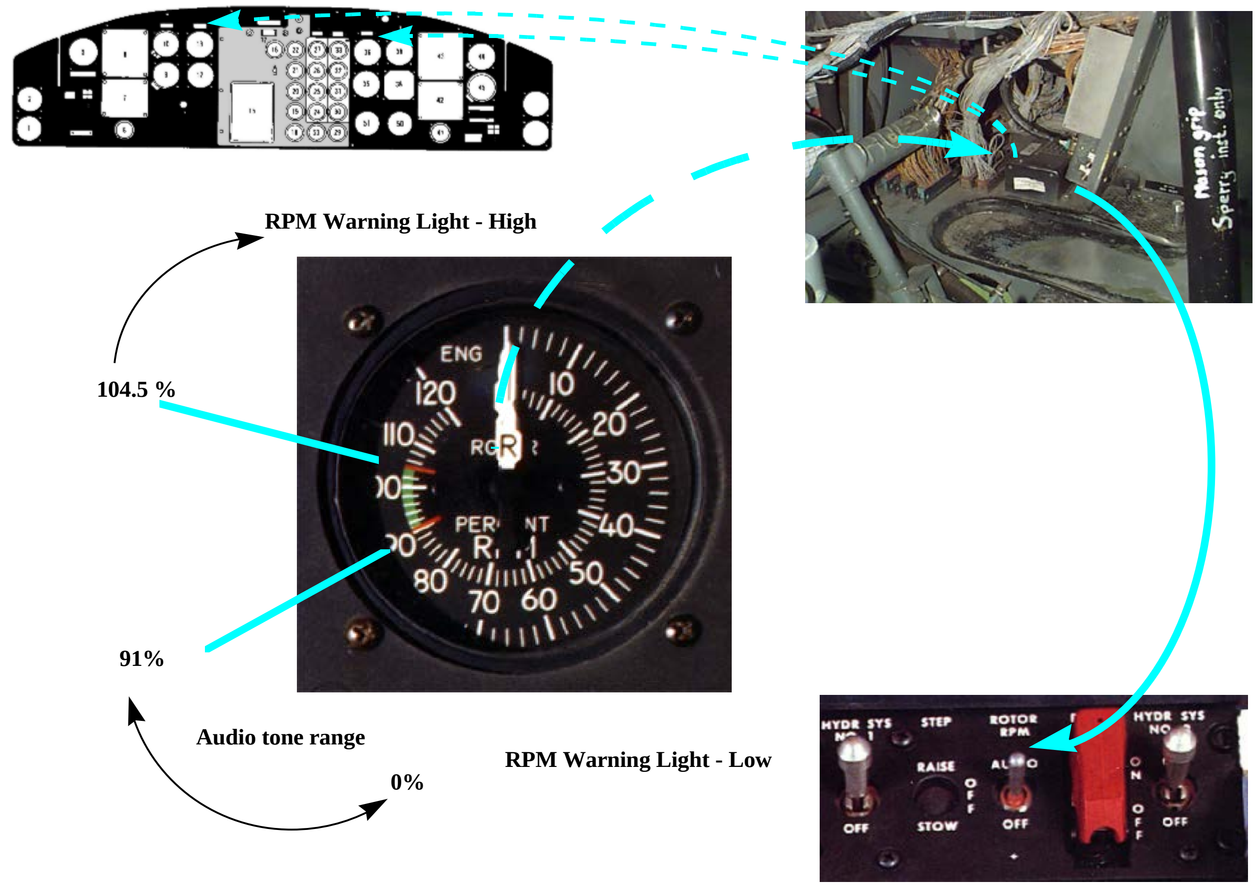

Figure 9-14 Rotor RPM Warning Systems

A ROTOR RPM switch, located on the center pedestal, is spring loaded to the AUDIO position: however, it may be moved to the OFF position to mute the rpm warning tone if desired. The switch (and RPM warning tone) remains off until the system resets itself when the rotor rpm increases through 93%.

LIMITATIONS

There are main rotor limitations for both powered flight and autorotative descents to ensure optimum aerodynamic efficiency. In flight rotor limits are provided in the "Limitations" section of the manufacturer's approved FM (Figure 9-14).

POWER ON

The main rotor system is designed to provide optimum efficiency in the range of 97 to 100% NR rpm and is indicated by the green range of the N2 scale of the triple tachometer.

POWER OFF

Power off flight rotor rpm limitations are 91 through 104.5% NR rpm and are indicated by the green range of the NR, or inner, scale of the triple tachometer.

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