

# Warnings

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**WARNING!**

**THE RADIO CONTROLLED MODEL HELICOPTER BUILT FROM THIS KIT IS NOT A TOY, AND IS NOT MEANT FOR CHILDREN. IT IS A FLYING MACHINE CAPABLE OF CAUSING PROPERTY DAMAGE AND SERIOUS BODILY HARM TO THE OPERATOR AND SPECTATORS IF NOT BUILT AND OPERATED CORRECTLY AND RESPONSIBLY. ROTATING COMPONENTS, ESPECIALLY THE MAIN ROTOR BLADES, ARE AN EVER-PRESENT DANGER.**

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**WARNING!**

Helicopters, by their nature, are not positively stable. Even if assembled and adjusted properly, helicopters will not hold a particular flight position without constant control inputs from the pilot, and will not automatically recover from an unwanted flight attitude without pilot intervention.

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**WARNING!**

It is your exclusive responsibility to correctly and responsibly build, maintain and operate this helicopter. Lite Machines has spent considerable time making this product reliable and easy to build, but only the operator can ensure that it is safe. Because the safe operation of this helicopter is beyond the control of the manufacturer and distributor, the owner/operator assumes all risk of use.

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**WARNING!**

**THIS PRODUCT CONTAINS CHEMICALS WHICH ARE KNOWN BY THE STATE OF CALIFORNIA TO CAUSE CANCER, BIRTH DEFECTS AND/OR OTHER REPRODUCTIVE HARM.** Many common materials, such as metals, plastics, glues, fuels, lubricants and coatings contain chemicals in varying amounts and concentrations which will cause harm if introduced into the human body. Lite Machines strives to produce safe and reliable products, and is interested in the well-being of every user of its products. For more information on chemicals contained in Lite Machines' products, please contact Lite Machines Corporation. For further information on toxic or dangerous chemicals, please refer to California's health and safety codes sections 25249.5-13.

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# Acknowledgments

We thank all of those people who helped make Lite Machines Corporation possible. We especially thank Mom and Dad. Without their help and constant encouragement we could not have done this.

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## **PATENT NOTICE**

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Most aspects of Lite Machines helicopters including, but not limited to, the main rotor, main rotor blades, tail rotor, tail rotor blades, *Arlton Subrotor*<sup>™</sup> stabilizer, *Arlton Gyro*<sup>™</sup> stabilizer, swashplate, fuselage structure and configuration, radio installation configuration, landing gear and drive train are either patented (U.S. 5305968, 5597138, 5609312, 5628620, 5749540, 5879131, 5836545, 5906476, 6053146, 6142419; Australia 681287, 686883; Europe 0605656, 95918276.7-2312, 95932305.6-2312, 96928019.7; France 0605656; Germany 69221307.4; U.K. 0605656), patent pending or patent applied-for in the United States and in other countries. For information concerning patents and licensing, please contact Lite Machines Corporation.

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# **Model Helicopter Safety**

This section contains important safety information regarding proper handling and operation of Lite Machines helicopters and accessories.

## **Fuel Safety**

1. Use **ONLY** commercial fuel developed for model engine use. **NEVER USE GASOLINE, DIESEL, OR ANY OTHER FUEL!** These fuels will ruin model engines, and can explode and burn causing injury to **YOU** and **OTHERS**.
2. **DO NOT OPERATE MODEL ENGINES INDOORS!** Hot engine parts and exhaust could ignite carpeting, drapery or furniture. Engine exhaust also contains large amounts of unburned oil that will soil interior furnishings.
3. Never fuel or prime with the glow-plug battery connected to the engine. Sparks from the electric connection could start a fuel fire.
4. Never fuel, prime, or operate your model while smoking.
5. Store fuel in a cool dry place protected from sunlight and from potential ignition sources (anything burning, or anything that could start a fire if exposed to fuel such as shorting or sparking battery terminals or the furnace in your home).
6. Remove excess fuel from your model with a cloth after refueling or priming. Raw fuel can damage paint and is a potential fire source.
7. Do not store fuel in your model.
8. Fuel is poisonous and can cause death or blindness if swallowed. If swallowed, induce vomiting and call for medical assistance immediately.
9. Fuel is an eye irritant. In case of contact with eyes, flush thoroughly with water.
10. Raw fuel will damage certain types of plastic. Prescription plastic lenses and the clear plastic commonly used on radio transmitter meters will be damaged if exposed to raw fuel (such as droplets sprayed from the engine during starting). Wipe off immediately using spray window cleaner.

### **IF FIRE SHOULD OCCUR:**

1. **MODEL FUEL BURNS WITH A NEARLY INVISIBLE FLAME, BE VERY CAREFUL!**
2. Use a fire extinguisher, or smother fire with a **CLEAN**, heavy cloth. If fire persists, **GET AWAY!** Better to lose the model than risk severe burns.

## Flight Safety

1. **ALWAYS WEAR APPROPRIATE EYE PROTECTION WHEN OPERATING YOUR MODEL.** Fuel droplets, loose parts, and airborne debris ejected from your model could cause serious injury or blindness. Select comfortable, well-fitting eyewear with high-impact resistance such as shop glasses. Prescription glasses made of glass are dangerous because they could shatter if struck sharply.
2. **ALWAYS WEAR APPROPRIATE HEARING PROTECTION WHEN STARTING AND ADJUSTING YOUR ENGINE.** Many car, airplane and helicopter modelers ignore the sound produced by the engines on their models. High volumes and high frequencies produced by model engines can damage hearing. This damage can be cumulative. Ear-phones and ear-plug style hearing protectors (sold in sporting goods stores in the gun section) are inexpensive and effective at reducing the most damaging and annoying qualities of engine sound. Once your model is started and flying, hearing protection is usually not necessary.
3. **NEVER STAND OR PLACE YOUR EYES OR FACE IN-LINE WITH ROTATING MAIN ROTOR OR TAIL ROTOR BLADES.** Loose parts or debris thrown outward from rotating rotors could cause injury or blindness.
4. **NEVER, EVER FLY NEAR OR OVER PEOPLE.** Always keep your model at a safe distance from yourself and spectators.
5. Use only those model engines designed specifically for your Lite Machines helicopter. Use of more powerful engines (such as racing engines) is potentially dangerous and voids all warranties.
6. Do not use fuel containing more than 35% nitromethane. The added power and heat of high nitro fuels can damage both the engine and your model.
7. Never allow main rotor speed to exceed 2000 RPM (as by operating with blade pitch set too low, or using a high powered engine with high nitro fuel). Rotor parts could separate from the rotor head and cause serious injury or property damage. Very high speeds can also damage the engine.
8. Fly only at approved flying fields or in open areas away from people and property. Do not fly in residential areas.
9. Before turning on your radio, ensure that your radio frequency is not already in use. Flying clubs have organized frequency sharing procedures.
10. Range check your radio prior to the first flight of each day. If your range check is lower than normal, do not fly.
11. Prior to the first flight of each day, check all mechanics for smooth, unobstructed operation. Before the main rotors reach flying speed, gently move all flight controls and confirm proper function. Do not fly if anything is out of the ordinary.
12. Check for hidden damage after crashing, and replace any damaged components.
13. Beginners should have the main rotors tracked, and model adjusted for flight by an experienced modeler.

## Electric Power Safety

1. Electric power systems can be very dangerous. High electric currents can heat wires, cause sparks and lead to fires and personal injury. **DO NOT TO TOUCH EXPOSED ELECTRIC COMPONENTS, AND NEVER FLY AT A SITE LOCATED NEAR FLAMMABLE MATERIALS.**
2. Electric motors are almost silent, and the main rotor and tail rotor blades of an electric helicopter can start turning unexpectedly causing serious injury. **MAKE SURE THE TRANSMITTER IS SWITCHED ON BEFORE CONNECTING THE SPEED CONTROLLER AND BATTERY ON AN ELECTRIC HELICOPTER. ALWAYS DISCONNECT THE BATTERY FROM THE SPEED CONTROLLER WHEN CARRYING AN ELECTRIC HELICOPTER.**
3. **ALWAYS DISCONNECT THE MOTOR POWER CABLES WHEN ADJUSTING THE RADIO SYSTEM ON A HELICOPTER SO THE MAIN ROTOR BLADES CANNOT START TURNING. TO AVOID A SHORT CIRCUIT, BE CAREFUL NOT TO TOUCH THE ENDS OF THE POWER CABLES TOGETHER.**
4. Electric power systems, electronic components and batteries contain chemicals such as lead and antimony which are known by the state of California to cause cancer and birth defects.

## General Safety

1. Periodically check tightness of all bolts, nuts, set screws and pins. Loose parts could be ejected from your model causing injury or causing the model to crash.
2. Replace broken or worn components with original parts only. To prevent recurring problems it is important to locate and understand the cause of failure (including pilot error).
3. Never modify any part of the main rotor, tail rotor system or drive train. Modifications could lead to part failure.
4. Always replace the main and tail rotor blades in sets if damaged.
5. Do not store your model in direct sunlight. Prolonged exposure to ultraviolet light can weaken some types of plastics.
6. When flying in very cold conditions be aware that metals and plastics (even flexible ones) can become brittle and break or shatter.
7. Keep your model, radio and field equipment clean and in good repair. While cleaning and maintaining your model you can often find and fix potential problems (such as loose or damaged parts) before they occur.
8. Do not use solvents to clean or degrease rotor blades. Solvents can attack the plastic and cause the blades to fail unexpectedly resulting in serious injury.



# Terminology and Controls

This section contains information on helicopter terminology and flight control functions. Review the figures and become familiar with the names and functions of the major components and controls. For more information on helicopter controls see the *How Helicopters Work* section of this Operator's Guide.

## Hint:

If you want lasting respect from helicopter flyers, don't call the main rotor and tail rotor blades "propellers", and don't call the right-left cyclic (pronounced sigh'-click) and fore-aft cyclic controls "aileron and elevator". This reveals your true identity as an airplane person and diminishes your credibility among helicopter pilots. Also, don't call the swashplate, "that thing with bearings in it connected to the main rotor."

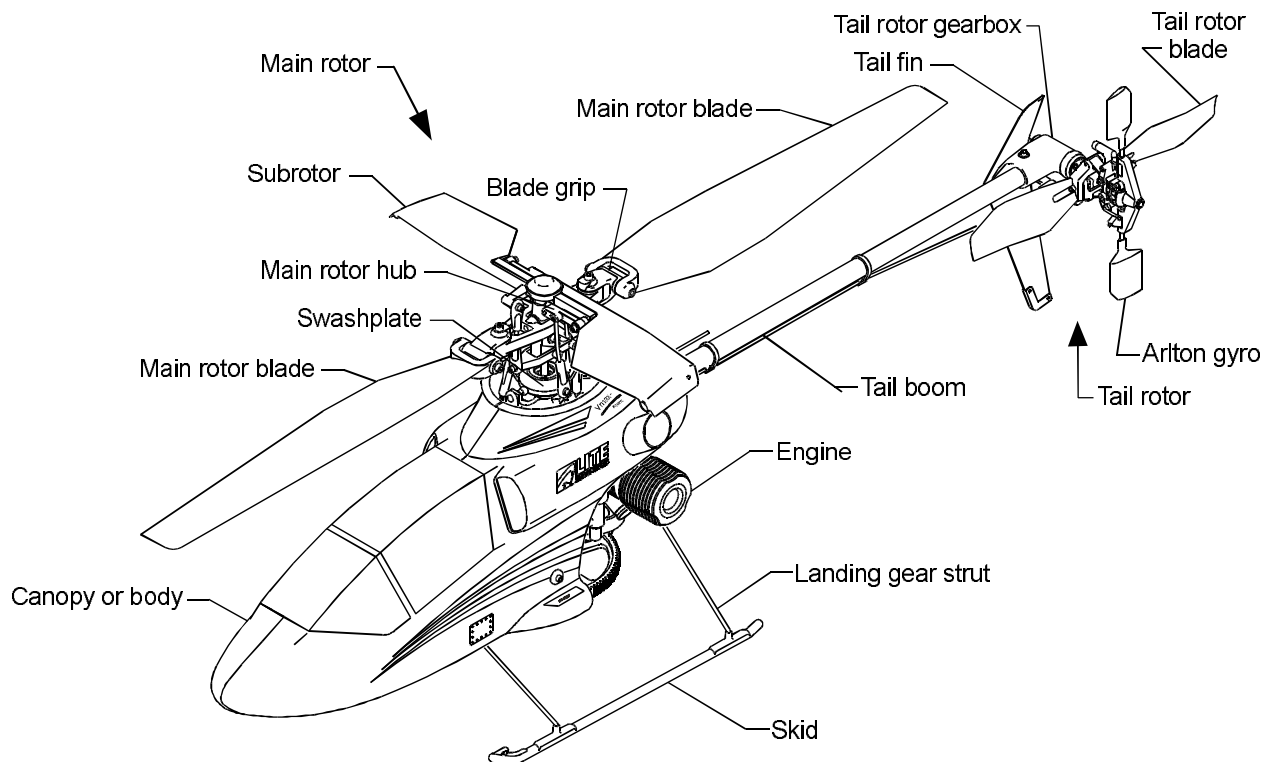
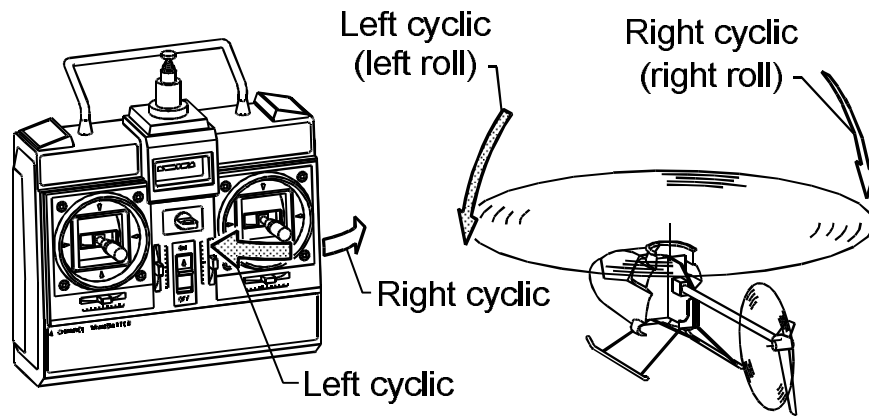


Figure 2-1.

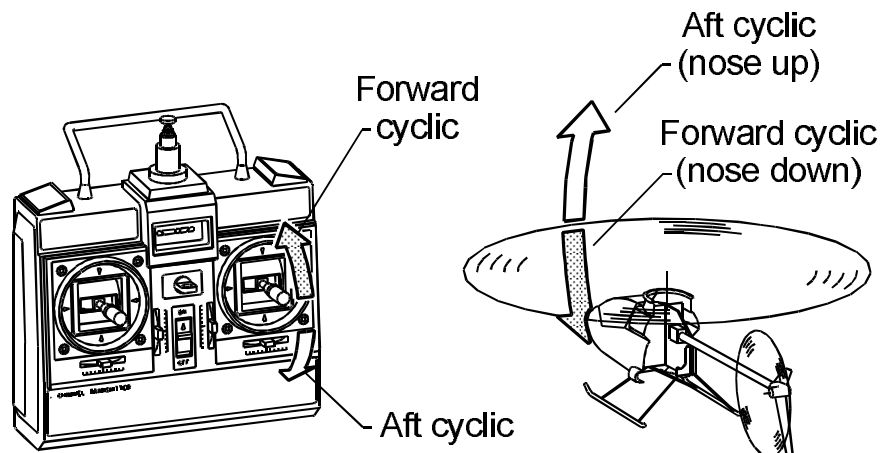
## Helicopter Controls

To fly a model helicopter you must first understand the function of each flight control. Fig. 2-2 through Fig. 2-5 illustrate the flight motions produced with the right cyclic (pronounced “sigh-click”) stick on the transmitter. The right stick tips the rotating main rotor in the direction of the stick motion and controls the direction of horizontal flight.



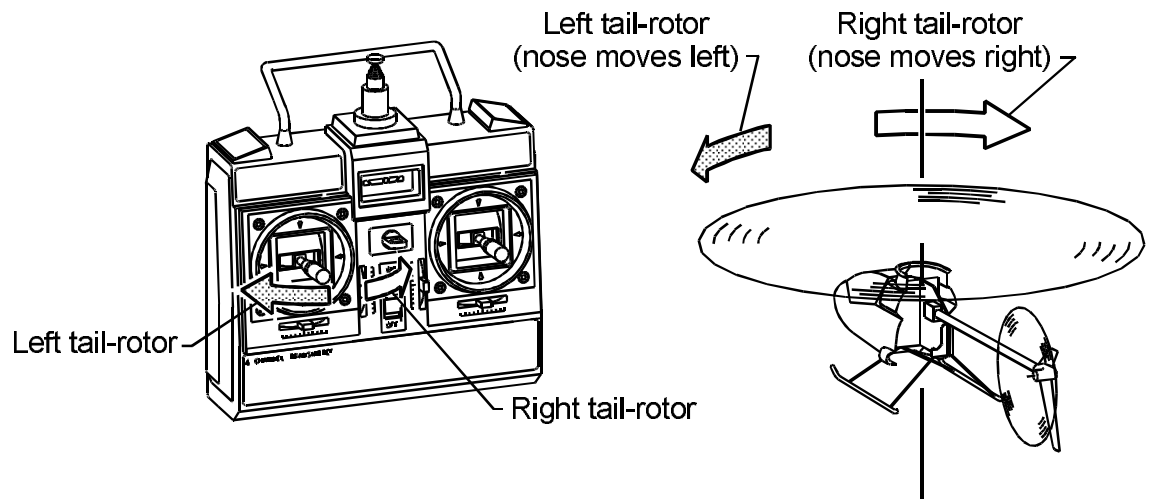
**Figure 2-2.**

As shown in Fig. 2-2, moving the stick left and right tips the main rotor left and right (like aileron control on an airplane).



**Figure 2-3.**

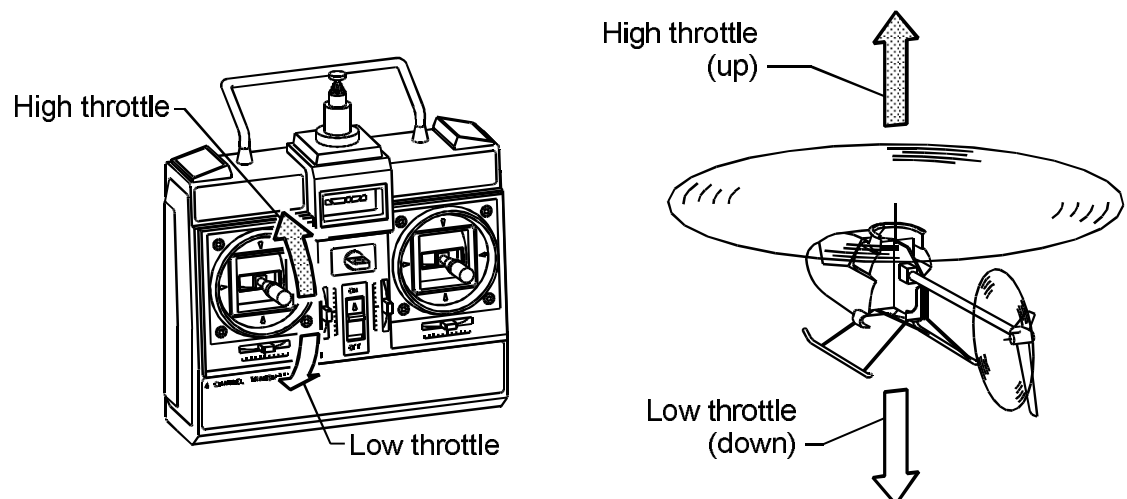
As shown in Fig. 2-3, moving the stick forward and backward (up and down) tips the main rotor forward and backward (like the elevator control on an airplane). When learning to use the right stick, it is helpful to think of it linked to an imaginary control stick mounted vertically on top of the main rotor. As you push the transmitter stick forward, you also push the imaginary control stick forward and tip the main rotor forward. Imagine the same for backward, left and right.



**Figure 2-4.**

Fig. 2-4 and Fig. 2-5 show the effect of moving the left stick on the transmitter. The left stick controls the tail rotor and throttle.

As shown in Fig. 2-4, moving the left stick to the left and right changes the pitch of the tail rotor blades causing the helicopter to rotate to the left or right (like steering a car). Note that the left stick rotates the **NOSE** to the left and right. Always concentrate on the **NOSE** when using the left stick to turn. You will become confused if you watch the tail.

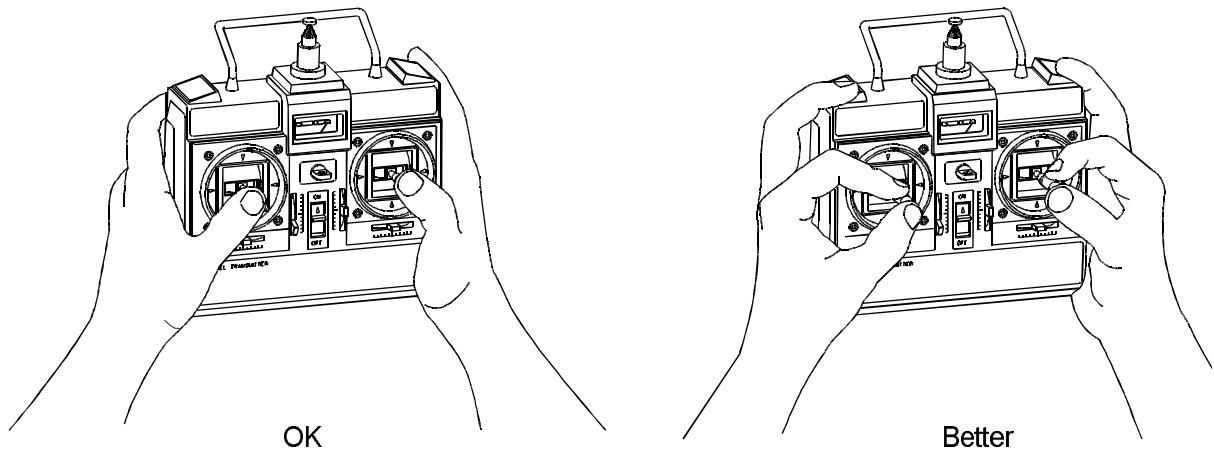


**Figure 2-5.**

Moving the left stick up and down increases or decreases engine speed causing the helicopter to climb or descend as shown in Fig. 2-5. On collective-pitch helicopters, the left stick also controls the pitch angle of the main rotor blades.

## Holding the Transmitter

Model airplane fliers commonly hold their transmitter so only their thumbs touch the transmitter sticks. When flying with thumbs, it is easy to unintentionally mix controls by moving the right stick up and to the right, and the left stick up and to the left.



**Figure 2-6.**

To control your helicopter more accurately, hold the control sticks with both your thumbs and index fingers as shown in Fig. 2-6. It also helps to wear a transmitter neck strap to support the transmitter and take the weight off your hands.

**Note:**

Even though the drawings show the transmitter antenna retracted, always extend your transmitter antenna before flying for the best possible radio range.



# **Electric Motors**

This section describes basic principles of electric powered flight and the operation of *Electro-Fusion* brushed motors. If you have a gas-powered helicopter you can skip this section.

## **The *Corona* Electric Helicopter**

Before it made its first flight, the *Corona* electric helicopter was optimized by a computer program to fly at maximum efficiency with *Electro-Fusion* brushed motors. The rotor systems and motors were matched to achieve the best lift-to-drag ratio of the rotor blades for a particular weight, speed and motor efficiency.

After computing the best design parameters, prototype parts were developed and tested on an instrumented whirl stand to generate test data (such as lift, drag and air velocity measurements) at dozens of points around the main rotor and tail rotor. The measurements were fed back into the computer program to further optimize the design.

There are many interrelated design variables in the *Corona* helicopter, so it is practically impossible to optimize the design by trial and error. A basic understanding of electric powered flight, however, will greatly aid you in successfully operating your *Corona* helicopter.

## **Basic Theory of Electric Power**

Electricity is commonly measured in units of volts (abbreviated "V"), amperes ("A"), ohms ("Ω") and watts ("W"). By analogy, electric current flowing through a wire is like water flowing through a pipe.

Electric potential is measured in volts (positive and negative) and can be thought of as pressure in a water pipe. If the pressure at one end of the pipe is higher than at the other end, the pressure difference will push water through the pipe. If there is no pressure difference, then no water will flow.

In a similar way, voltage difference in a wire pushes electrons through the wire from the negative end of the wire to the positive end. If there is no voltage difference, no electrons will flow. A seven-cell NiCad battery pack produces about 8.4 volts of electric potential.

Electric current is measured in amperes ("amps" for short), and is related to the amount of electrons (actually electron waves) flowing through a wire. A large diameter wire can conduct more electrons than a small wire in the same way a large

diameter pipe can carry more water than a small pipe. The *Corona* electric helicopter normally flies on about 11 to 19 amps of electric current.

Electric resistance is measured in ohms and represented by the Greek letter omega ( $\Omega$ ). Resistance slows down or inhibits the flow of electrons in a wire like a plug slows down the flow of water in a pipe. When electric resistance inhibits the flow of electrons, the energy of the electrons is converted to heat (this is how an electric stove works). The *Fusion 35* motor speed controller has an internal resistance of only about 0.005 ohms (this is really low), and, as a result, stays cool in operation.

Power is measured in watts which is simply amps multiplied by volts. A *Corona* electric helicopter drawing 12 amps from an 8.4 volt battery consumes 100.8 watts of power ( $12A \times 8.4V = 100.8 W$ ).

## Batteries

Batteries store electric energy in various ways, but each type of battery has a characteristic voltage and a maximum current storage capacity. The Nickel-Cadmium (NiCad) battery cells used in your *Corona* helicopter each produce a maximum of about 1.2 volts.

Batteries can be connected end-to-end in “series” to increase voltage or side-to-side in “parallel” to increase current capacity. Six-cells connected in series to form a standard six-cell pack produce about 7.2 volts ( $1.2V \times 6 \text{ cells} = 7.2 \text{ volts}$ ). Seven-cells connected in series produce about 8.4 volts ( $1.2V \times 7 \text{ cells} = 8.4 \text{ volts}$ ).

Battery capacity is measured in milliampere hours which is abbreviated “milliamp-hours” or “mAh”. A milliamp represents  $1/1000^{\text{th}}$  of an amp of current (0.001 A), and a milliamp-hour represents  $1/1000^{\text{th}}$  of an amp of current flowing for one hour. A 2400 mAh battery can produce 2400 milliamps of current for one hour. This is the same as 2.4 amps for one hour, 1.2 amps for two hours or 0.6 amps for four hours.

All batteries and motors have internal resistance that causes them to heat up in operation. The more current flowing through a battery or motor, the more heat produced. Since the idea behind electric power is to convert the electric energy stored in a battery to mechanical energy, any heat generated is a measure of inefficiency and waste. Generally, expensive batteries have lower internal resistance than cheap batteries, and provide longer flight times with more available power.

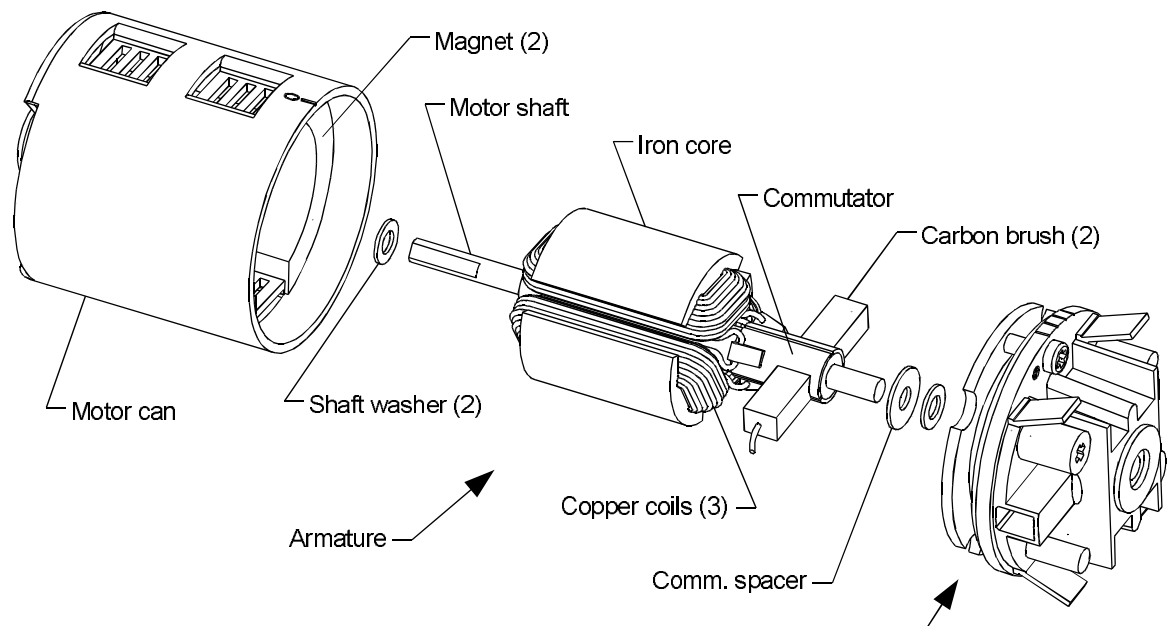
## Electro-Magnetism and Electric Motors

When electric current flows through a coil of copper wire, the current generates a magnetic field (also called an “electro-magnetic” field). The strength of the magnetic field depends on the voltage, current and number of winds in the coil. The strength of the field can be greatly increased by winding the coils around a chunk of iron metal.

Like all magnets, electro-magnets have a north pole and south pole. North and south poles attract each other. When two magnets are placed next to each other, the magnets tend to rotate so the north pole of one magnet aligns with the south pole of the other.

Electric energy stored in a battery can be converted to mechanical energy by an electric motor which uses electro-magnetic fields to rotate an output shaft. Model motors come in two basic varieties, “brushed” and “brushless”, which differ in terms of how electric current gets to the copper coils or “windings” inside the motor.

## Brushed motors



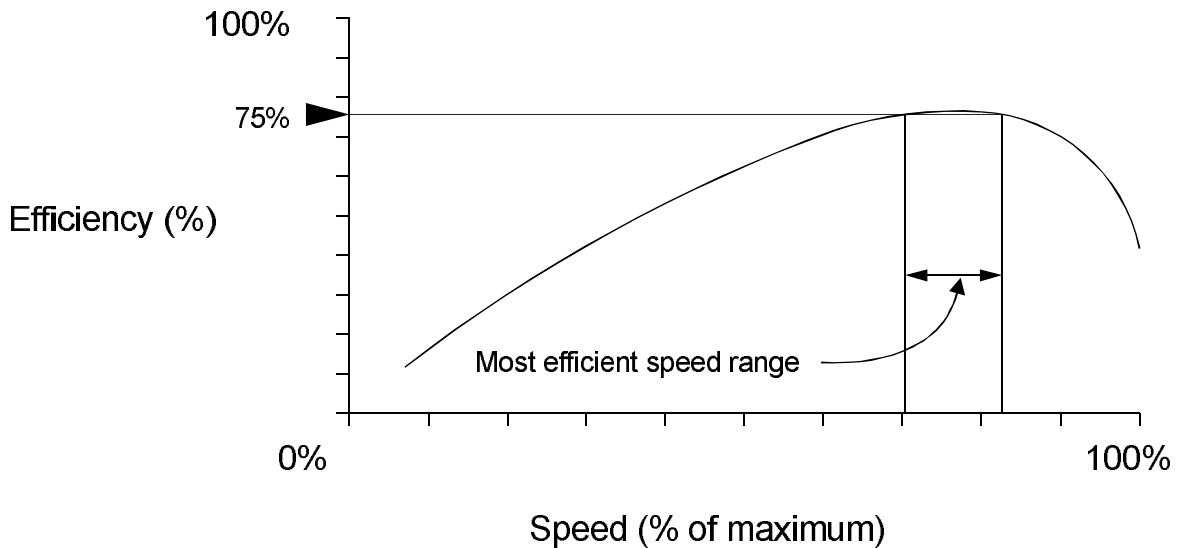
**Figure 3-1.**

In a “brushed” motor, electric current flows through carbon brushes that slide on a copper commutator ring attached to the motor output shaft as shown in Fig. 3-1. The commutator ring generally has three segments attached to three coils of copper wire each wrapped around an iron core. The motor shaft, commutator, coils and iron core are collectively referred to as the motor “armature”.

As the armature rotates, the brushes conduct current to each segment on the commutator and through one coil after another. The energized coils produce magnetic fields that pull the coils toward permanent magnets mounted on the inside of the motor body (also called the motor “can”). As each coil passes a permanent magnet, the brush associated with that coil slides onto the next commutator segment. This de-energizes the coil and energizes the next one in sequence.

The speed of rotation of a brushed motor is determined by the load on the motor, the amount of current passing through the coils, the number of turns or winds in the coils and the operating voltage. Motors running at high voltage are generally more efficient because less current is needed to generate power, so less energy is lost as heat. Also, motors with fewer turns have more power and run faster, but are generally less efficient than motors with more turns.

Brushed motors are easy to manufacture, but are inefficient to operate. Only about 75% of the electric energy entering the motor is converted to mechanical energy. The rest is converted to heat by the electric resistance of the brushes and by conflicting magnetic fields inside the motor.



**Figure 3-2.**

As shown in Fig. 3-2, which is a graph of motor efficiency at various motor speeds, brushed motors are most efficient within a very small speed range. Outside of this range efficiency drops quickly, and most of the electric energy entering the motor is converted to heat. When a motor operates outside its efficient speed range the motor body becomes very hot (sometimes too hot to touch), and the motor coils can burn out.

## Adjustable Timing

Motor coils cannot energize instantly when current is applied. This poses a problem for brushed motors running at high speed because the coils energize at the wrong time and generate conflicting magnetic fields that push on the permanent magnets when they should be pulling (and vice versa). Some brushed motors, such as the *Electro-Fusion* motor on your *Corona* helicopter, have adjustable timing to address



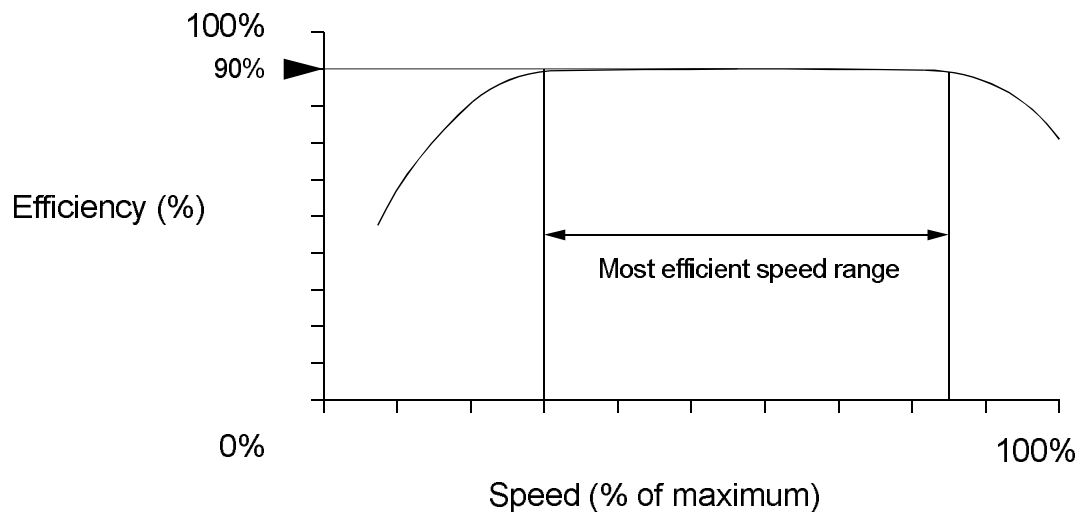
this problem. To adjust the point at which the brushes touch the commutator segments, the motor end-bell can be rotated relative to the motor body.

“Advanced” timing gives the coils more time to develop a strong magnetic field so they can pull on the permanent magnets longer and with less magnetic conflict. Timing of the *Electro-Fusion* motor on the *Corona* helicopter is usually set between 15 and 20 degrees for best results.

## Brushless Motors

Brushless motors require no brushes. The copper coils are usually located on the outer surface of the motor case (instead of on the spinning armature) where they can be connected directly to a power supply. The permanent magnets are mounted on and rotate with the output shaft. A small, computerized speed controller turns the coils on and off at the appropriate time to operate the motor at a particular speed.

Brushless motors are more difficult and expensive to manufacture than brushed motors, but are more efficient and powerful. With no brushes to burn out, the coils can carry very high currents. Since the computer operated speed-controller can be programmed to turn the coils on and off at just the right time, the power loss associated with conflicting magnetic fields is very low.



**Figure 3-3.**

Efficiencies of good brushless motors approach 90% (that is, 90% of the battery power going into a brushless motor ends up rotating the output shaft). As shown in Fig. 3-3, brushless motors also can operate efficiently over a wide speed range. At such high efficiencies, brushless motors tend to run cooler than brushed motors because less electric power is wasted as heat.

## Problems with Brushed Motors

*Electro-Fusion* motors are modified versions of standard 540-size brushed motors. The original 540-size motors made in the 1980's produced about 50 watts of power, but *Electro-Fusion* motors can produce as much as 150 watts with the same size brushes. Since the brushes and commutator on modern motors handle more power, they wear down more quickly. Brush and commutator wear is the primary source of power loss in brushed motors.

Motor brushes are typically made of carbon, copper and silver, and vary in hardness. When a brushed motor turns at high speed, the ends of the brushes and commutator slide against each other and wear down. If the brushes have hard spots, or wear unevenly, the commutator can also wear unevenly. As the gap between the commutator and brushes becomes more uneven, small sparks jump between the brushes and commutator and accelerate the wear of both. This uneven gap also increases electric resistance.

As resistance goes up, so does the heat generated by the current flowing through the brushes and commutator. This heat eventually burns the brushes and turns them a deep blue color. When this happens, brush manufacturers say, certain lubricating components are burned out further accelerating brush wear.

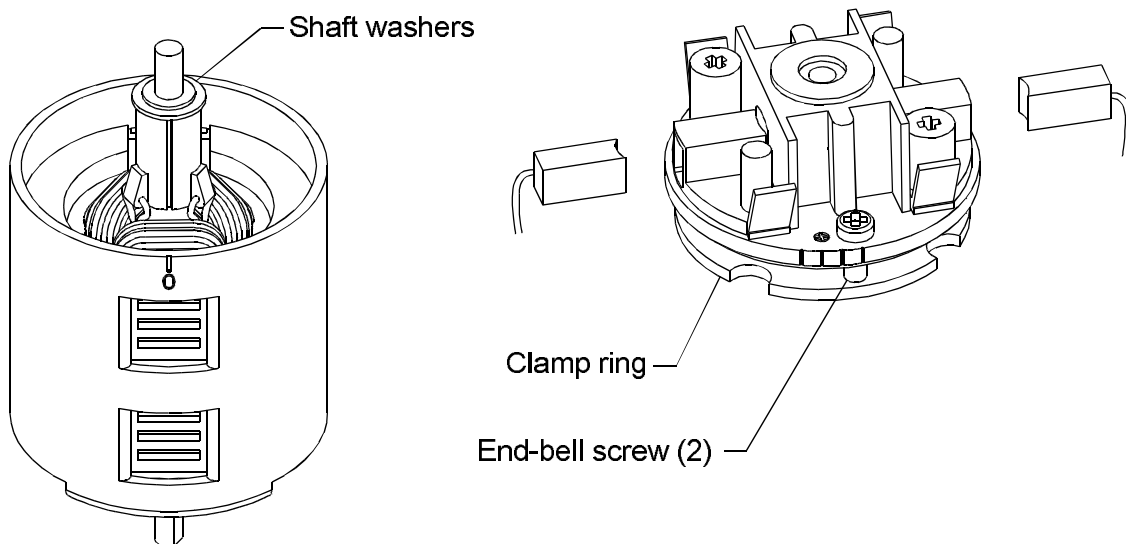
Once a brush has worn down to the point where it no longer touches the commutator it must be replaced. If the commutator wears unevenly, it must be resurfaced on a commutator lathe or the entire armature must be replaced.

Commutator surface finish is possibly the most overlooked problem with brushed motors because relatively few modelers take apart and inspect their motors. As high electric currents pass between the motor brushes and commutator, the surface of the commutator heats up and oxidizes turning a deep black color. This black finish increases the electric resistance of the commutator/brush connection and consumes battery power. Removing the black surface finish can restore electric conductivity and proper commutator function.

## Three-Minute Motor Overhaul

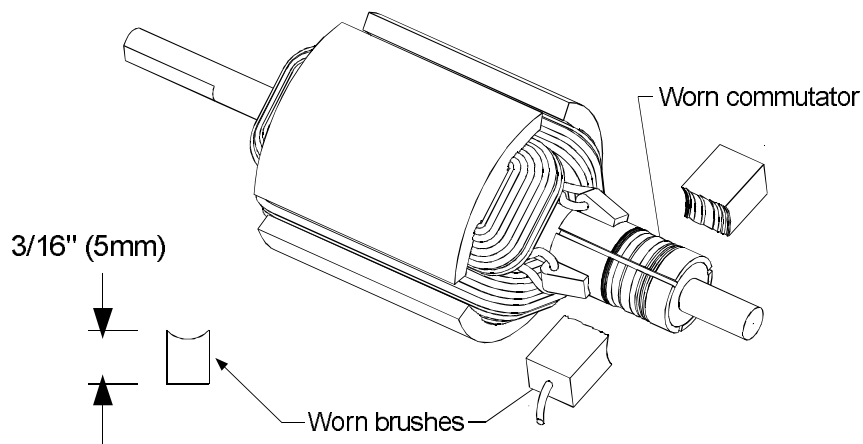
For the best long-term performance of your *Electro-Fusion* motor, service your motor every six to ten flights using this simple three-minute procedure.

1. Disconnect the flight battery from the speed controller, and the power cables from the motor, but leave the motor in your *Corona* helicopter.
2. Remove the motor pinion gear.
3. Pull the brushes out past the end of the brush springs so the brushes do not catch on the commutator washer.



**Figure 3-5.**

4. Loosen (but do not remove) the end-bell screws. Rotate the end-bell assembly, and pull it off the motor as shown in Fig. 3-5.
5. Remove the armature from the motor can.



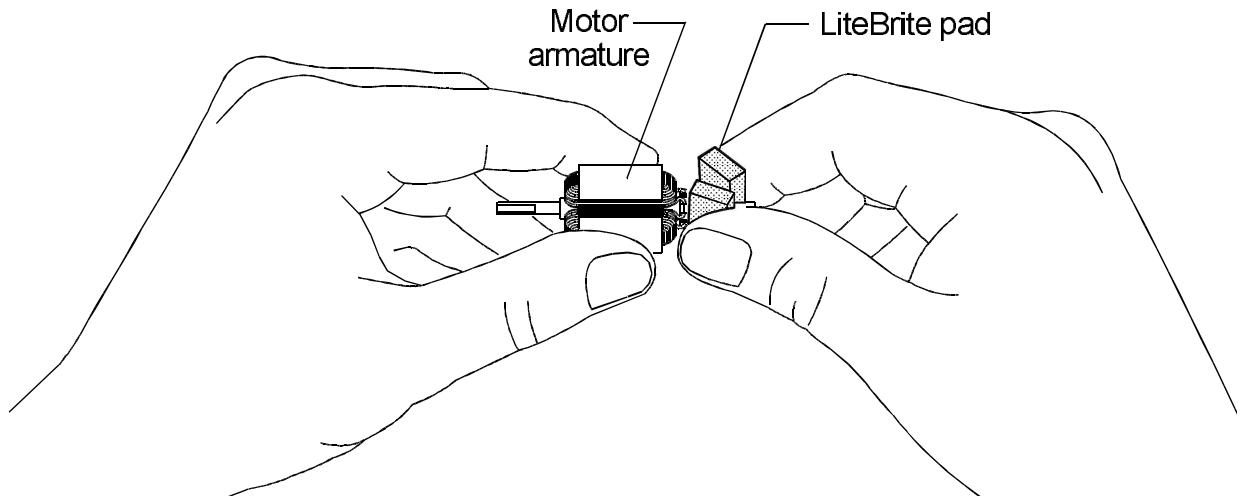
**Figure 3-4.**

6. Inspect the brushes. If the brushes are less than 3/16" (5 mm) long, or if the brushes are burnt and discolored, replace with new ones.

### Warning!

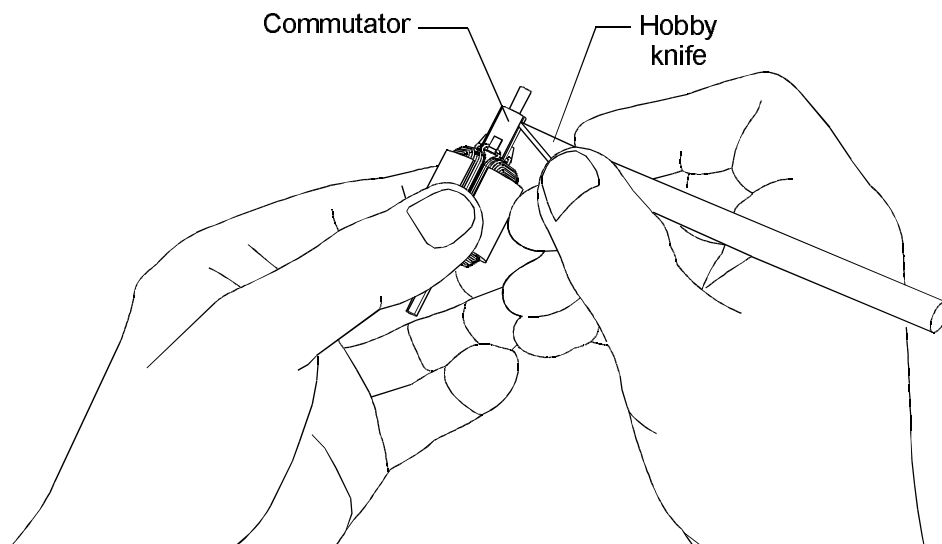
**DO NOT USE REPLACEMENT BRUSHES WITH A SERRATED OR WAVY RUNNING SURFACE.** The serrated surface will cut into the commutator and damage it.

7. If the commutator is worn unevenly as shown in Fig. 3-4, replace the entire armature with a new one. This will significantly increase motor power.



**Figure 3-6.**

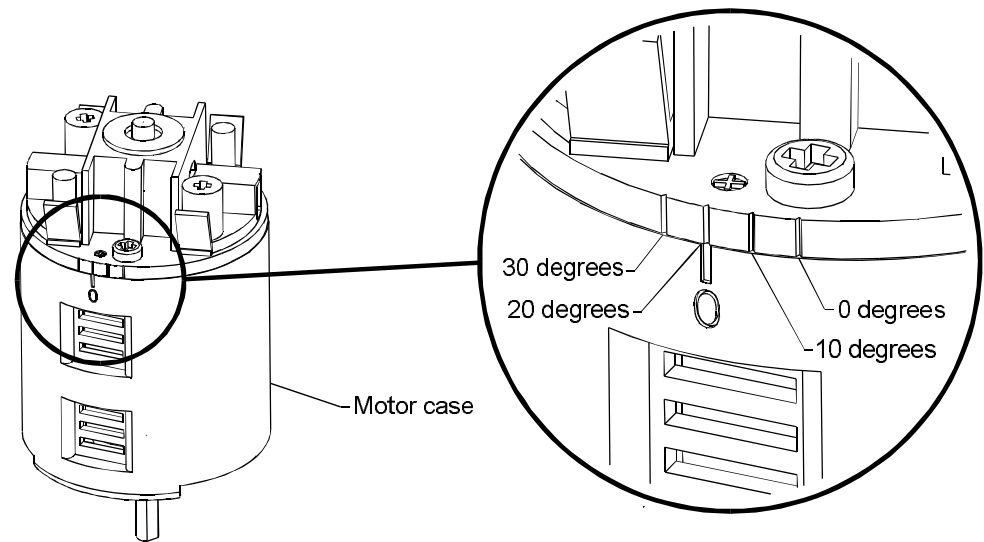
8. If the commutator surface is smooth but dark and discolored, clean it with a LiteBrite commutator cleaning pad until it is a shiny copper color (six to ten twists by hand) as shown in Fig. 3-6.



**Figure 3-7.**

9. Run a hobby knife in the slots between the commutator segments to remove loose particles as shown in Fig. 3-7.

10. If the commutator was clean when you opened the motor, wait a few more flights before cleaning it the next time. If it was dark and discolored, clean it more frequently.
11. Clean the inside of the motor can and motor end-bell with a paper towel.
12. Lightly lubricate the motor shaft with Lite Lube heavy oil, and install the armature in the motor can. Do not oil the commutator segments because the oil will quickly wear off and stick dirt to the inside of the motor.



**Figure 3-8.**

13. Make sure the plastic shaft washers are properly installed, and reassemble the end-bell to the motor case. Set the end-bell timing mark between 15 and 20 degrees as shown in Fig. 3-8, and tighten the end-bell screws. Do not over-tighten the end-bell screws or you will bend the internal locking ring.

## The *Fusion 35* Speed Controller

The *Fusion 35* brushed motor speed controller by Castle Creations is a specially designed microprocessor-based switching controller capable of delivering up to 35 amps of current to your *Electro-Fusion* brushed motor. The *Fusion 35* controller switches battery current on and off at up to 2800 times per second to control motor speed.

Battery elimination circuitry (BEC) in the *Fusion 35* controller supplies power to the receiver and servos on your *Corona* helicopter, and eliminates the need for a separate receiver battery. Built in filtering capacitors reduce electrical noise and possible radio interference generated by the motor brushes. A special arming feature reduces the possibility of accidental motor starting, and a soft-start function smoothly accelerates the rotor blades to reduce the possibility of gear train damage. If the radio

receiver loses transmitter signal for more than two seconds, an additional safety feature turns off power to the motor.

**Warning!**

Electric power systems can be very dangerous. High electric currents can heat wires, cause sparks and lead to fires and personal injury. **DO NOT TO TOUCH EXPOSED ELECTRIC COMPONENTS, AND NEVER FLY AT A SITE LOCATED NEAR FLAMMABLE MATERIALS.**

**Warning!**

Electric motors are silent, and the main rotor and tail rotor blades of an electric model helicopter can start turning unexpectedly or uncontrollably causing serious injury. **ALWAYS USE CAUTION AND MAKE SURE THE TRANSMITTER IS SWITCHED ON BEFORE CONNECTING THE SPEED CONTROLLER AND BATTERY ON A HELICOPTER.**

**Warning!**

**ALWAYS DISCONNECT THE MOTOR POWER CABLES WHEN ADJUSTING THE RADIO SYSTEM ON A HELICOPTER SO THE MAIN ROTOR BLADES CANNOT START TURNING UNEXPECTEDLY, AND BE CAREFUL NOT TO TOUCH THE ENDS OF THE POWER CABLES TOGETHER TO AVOID A SHORT CIRCUIT.**

## Arming the *Fusion 35*

To reduce the possibility of accidental starting of the main rotor blades, the *Fusion 35* controller will not deliver motor power until it is armed. To arm the *Fusion 35*, perform the following steps.

1. Insure that all controller and motor connections are correct, and that the *Fusion 35* controller is plugged into the throttle channel on your radio receiver.
2. Turn on your transmitter and make sure the transmitter batteries are charged.
3. Connect your *Fusion 35* controller to your battery (you should hear a single beep from the motor).
4. If this is the first time you are running this controller or receiver, disconnect the motor power cables and perform a radio range check. If the range check is good, then reconnect the motor cables.

**Warning!**

**DO NOT RANGE CHECK YOUR RADIO WITH THE MOTOR POWER CABLES CONNECTED. IF THE RECEIVER LOSES TRANSMITTER RADIO SIGNAL THE MOTOR COULD START UNEXPECTEDLY.**

5. Move the transmitter throttle stick to full-low for two seconds. You should hear the motor beep once.

6. Move the throttle stick to middle-stick position for two seconds. You should hear the motor beep again.
7. Move the throttle stick back to full-low for two seconds. You should hear the motor beep twice and your *Fusion 35* is now armed.

**Note:**

---

If electrical noise becomes excessive, or if radio signal is lost for more than two seconds, the *Fusion 35* will disarm and stop the motor. To rearm, hold the throttle stick in full-low for four seconds.

---

## Optional RF Filter

The *Fusion 35* controller includes built-in filter capacitors to reduce the radio interference generated by electric motors commonly referred to as “radio-frequency interference,” “RF noise” or “electrical noise”. **DO NOT** install additional filter capacitors between the motor power cables and motor case because this will interfere with the proper operation of the *Fusion 35* controller.

If radio interference becomes a problem, you may install a single 0.1  $\mu\text{F}$  ceramic disk capacitor between the unused motor solder tabs. This will reduce electrical noise. After modifying or adding filter capacitors, always test your motor, controller and radio before flying.

**Warning!**

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**DO NOT USE TANTALUM OR ELECTROLYTIC CAPACITORS AS ELECTRICAL NOISE FILTERS BECAUSE THEY CAN EXPLODE AND/OR CAUSE FIRES AND BURNS.**

---

## Cable Connections

The *Fusion 35* controller includes a factory-installed Lite Machines connector on the battery power cable. You must install a corresponding Lite Machines connector to the wire leads on your battery pack and check the connections to your controller to insure proper polarity.

Generally, the red (positive) wire of your speed controller should be connected to the red (positive) wire on your battery pack. Similarly, the black (negative) wires should be connected to each other. For more information on battery connections, see the *Battery* section of the *Corona Construction Manual*.

The push-on, spade-style connectors on the motor side of your *Fusion 35* controller should fit firmly onto the solder tabs of your *Electro-Fusion* motor. If the tabs are too loose or too tight, adjust them carefully with a pliers or small screw driver.

**Warning!**

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**IF THE POSITIVE AND NEGATIVE BATTERY CONNECTIONS TO YOUR SPEED CONTROLLER ARE REVERSED, YOU WILL PERMANENTLY DAMAGE YOUR SPEED CONTROLLER. THIS DAMAGE IS NOT COVERED UNDER WARRANTY.**

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**Warning!**

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Do not install a fuse between your speed controller and battery. If the fuse blows the controller and radio receiver will have no power.

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**Warning!**

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Always perform a radio range check after installing a new speed controller. **IF YOUR RADIO DOES NOT PASS A RANGE CHECK, DO NOT FLY.**

---

## Battery Elimination Circuitry (BEC)

The battery elimination circuitry (BEC) in the *Fusion 35* controller powers the airborne radio control system in your *Corona* helicopter, so you do not need a separate receiver battery. The BEC will operate with battery packs having up to ten NiCad cells, but works best with packs of six to eight cells. Packs with over eight cells develop higher voltages that the BEC must reduce in order to power the radio receiver and servos. The voltage reduction process generates heat that wastes battery power.

If you wish to use more than ten cells in your battery packs you must use a separate battery to power your radio control system. To do so you must first cut the red power wire from your *Fusion 35* controller to the receiver (contact *Castle Creations* before doing this). Insulate the exposed end of the cut wire so it does not short circuit the controller or battery. Be sure to test your radio system before flying your *Corona* helicopter after this or any other modification.

## Charging Batteries

The *Corona* helicopter is designed to operate with *Electro-Fusion* brushed motors and either six or seven-cell sub-C NiCad battery packs. *Electro-Fusion 7* motors work best with seven-cell packs. *Electro-Fusion 6* motors work best with six-cell packs.

The *Corona* helicopter generally performs best with seven-cell packs because the added weight increases main rotor speed in hover (which increases stability). Seven-cell packs also produce higher voltages (8.4 vs. 7.2 volts) which increase maximum motor power. If you decide to use six-cell battery packs, purchase a specially configured *Electro-Fusion 6* motor to improve flight times.

While NiCad batteries can be fast-charged hundreds of times, it is best to “condition” new battery packs before use on a *Corona* helicopter. To condition a new battery pack, charge it slowly over night at a current of 1/10 of the rated battery capacity. For



instance, charge a new 2400 mAh battery pack at about 240 mA for ten hours before flying it on your helicopter or fast-charging it at a high current (3-5 amp) setting.

Since flight times generally run in the range of five to seven minutes, but charging times run thirty to sixty minutes, it is best to charge several battery packs for each flying session. For best performance, recharge or peak-charge batteries immediately before flying, and do not let charged batteries sit overnight. Batteries that have been left in a fully-charged condition overnight sometimes exhibit an “overnight effect” which limits the amount of power they can deliver in the morning. Discharging and recharging these batteries usually reverses this effect.

NiCad batteries that are repeatedly discharged to the same level can develop a discharge “memory”. Subsequent discharges will tend to stop at this level effectively limiting battery output. To prevent discharge memory from developing, always completely discharge your battery packs (by flying your *Corona* helicopter) before recharging them or storing them for extended periods of time.

Since NiCad batteries lose power rather quickly at the end of a flight, it is a good idea to time your flights with a watch. This will insure you are close to the ground when the batteries get low.

## Warning!

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**NEVER STORE BATTERIES IN A CHARGED STATE, OR CARRY CHARGED BATTERIES TOGETHER OR WITH ANYTHING THAT CONDUCTS ELECTRICITY.** The batteries can short circuit and cause serious fires, personal injury and property damage.

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## Battery Chargers

Battery chargers and proper charging technique are very important to the successful long-term operation of your *Corona* electric helicopter. A poorly designed or malfunctioning charger can permanently damage your battery packs in one or two charges, and reduce the maximum power they produce. Considering that you may eventually invest hundreds of dollars in batteries to power your radio-controlled models, it is best to purchase a high quality charger from the start, rather than purchasing an inexpensive charger first and ruining several expensive battery packs.

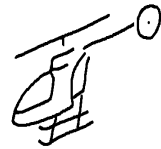
Some computer controlled fast-chargers can be connected to a wall outlet or a standard 12-volt automobile battery, and some display the battery charging parameters on a computer screen. The computer screen provides important information about the charging status and capacity of your batteries, and can give you clues to problems in your electric system such as when a cell in your battery pack is going bad.

## Flying Weight

Proper flying weight is an important factor in electric helicopter flight. Without enough weight, the main rotor blades turn too slowly, and stability and control power are reduced. This is especially noticeable in high winds. For this reason, a heavier seven-cell battery is preferred over a lighter six-cell battery in the *Corona* helicopter.

The *Corona* helicopter is designed to operate efficiently with an *Electro-Fusion 7* motor and a seven-cell NiCad battery at a flying weight of about 44 ounces (1250 g). The *Corona* flies best with an *Electro-Fusion 6* motor and six-cell battery at a weight of about 42 ounces (1190 g). While the *Corona* will lift more weight than this, too much weight can overload a brushed motor and reduce flight times. If you want to lift a heavy scale fuselage then consider using a brushless motor.

Flight times generally increase by about one second for each gram of weight removed. Removing a 40 gram (1.5 ounce) canopy will increase flight times by about 40 seconds. Many people practice hovering without a canopy, but it is best to install the canopy for forward flight so you can tell which way your helicopter is going when it is far away from you.



# Glow-Fuel Engines

Lite Machines gas helicopters are powered by Norvel *Vmax-6* and *Vmax-7* helicopter engines. In both engines, the crankshaft is supported by one or more durable bronze bushings to withstand the side-loads generated by gear driven rotor systems. Each engine has five directional transfer ports for easier starting and extra lugging power. The unique throttle/muffler design provides precise throttle control, and traps exhaust gases inside the cylinder to keep the glow plug hot for a lower, more reliable idle. The *Vmax-7* engine further includes a thermal insulator between the muffler and crankcase to reduce the flow of heat from the muffler to the engine, and six mounting lugs to support the increased power.

## General Operating Considerations

If you are a beginner, you can cut your learning time in half by locating someone who knows about Norvel engines and Lite Machines helicopters. Local hobby shops usually have a list of model airplane/helicopter clubs in your area. Whether you fly a helicopter or an airplane, you should not fly alone.

### Warning!

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**MAKE SURE SOMEONE IS ALWAYS NEARBY TO HELP YOU IF YOU NEED ASSISTANCE OR HURT YOURSELF WHILE OPERATING YOUR HELICOPTER. ADULT SUPERVISION IS STRONGLY RECOMMENDED FOR MINORS.**

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Operating conditions can affect engine life. Helicopters operate close to the ground, and kick up dust and sand that can scratch the inside of the piston cylinder, or clog the carburetor making the engine impossible to start or adjust. Avoid flying over loose dirt, and use a fuel filter to remove dirt from the fuel.

Over time, you will learn to gauge the condition of your engine by the sound it produces. A high-pitched, even tone usually means the engine is running well. A slightly lower tone, with an uneven warble may indicate that the engine is too hot or overloaded. If you have engine problems, refer to the *Engine Trouble-Shooting* section of this Operator's Guide.

## Fuel Mixture and Compression

The two most important factors affecting the performance of your Norvel engine are fuel/air mixture and compression. In operation, air and fuel enter a piston engine through the carburetor and flow into the cylinder above the piston. As the piston moves up within the cylinder, it compresses the fuel/air mixture against the hot glow plug at the top of the cylinder. At a certain point the fuel/air mixture ignites, pushing the piston down and producing useful power.

The needle valve on the carburetor meters the amount of fuel mixed with the air. Too much fuel (too "rich") causes the engine to slow down and lose power. Too little fuel (too "lean") causes the engine to over-heat, slow down and lose power. *Vmax* engines operate best within a needle valve range of about +1/4 to -1/4 turn.

Proper compression is needed for a reliable idle as well as maximum power. Compression is adjusted on *Vmax* engines by inserting or removing thin copper washers under the glow plug. If compression is set too high, the fuel/air mixture ignites too soon. This does not affect top-end power appreciably, but the engine may stop abruptly while idling. If compression is too low, the engine may not produce enough power for normal flying.

Compression is affected by air density. Anything that increases or decreases air density increases or decreases compression. The elevation of your flying site and the local temperature both affect air density and have a major influence on compression.

As elevation and air temperature increase, air density decreases. To maintain the same compression at high elevations and air temperatures, the volume in the cylinder above the piston must be reduced slightly by removing washers from under the glow plug.

For instance, if you fly at a high elevation (5000 ft or 1524m at Denver, Colorado, USA), you will use fewer washers under the glow plug than at a lower elevation (700 ft or 213m at Lafayette, Indiana, USA). Also, if you fly when the outside air temperature is 75°F (24°C), and the temperature drops to 40°F (4°C) you may need to add additional glow plug washers before flying again. The large temperature drop will otherwise affect engine idle because the cold, dense air increases compression.

When air density decreases, less fuel and air enter the engine on each piston stroke. This means that the engine will not produce as much power at high elevations or high temperatures where the air is thin. Lift produced by the main rotors depends upon air density in a similar way. The performance of all aircraft (including full size helicopters) degrades considerably at high elevations and on hot days.

---

**Hint:**

The compression rules for *Vmax-6* engines are to start with 15% nitro fuel and two washers under the glow plug. Add an additional washer for each 5% of nitro above 15%, and add an additional washer if the outside air temperature drops below 50°F (10°C). Remove one washer for every 2000' (600m) above sea level. For example, with 25% nitro fuel start with four washers. If the air temperature is 40°F (4.4°C) add one washer. If flying at 3000' (900m) remove one washer.

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**Hint:**

*Vmax-7* engines generally prefer high nitro (25%) and high compression, so use two to three fewer washers on the *Vmax-7* than on the *Vmax-6*.

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## The Importance of Clean Fuel

All model glow-fuel engines use a glow plug containing a platinum metal coil. The platinum metal in the coil acts as a catalyst and ignites the air/fuel mixture in the engine. To operate properly, the air/fuel mixture must actually touch the surface of the platinum coil.

If the surface of the coil is coated with anything, even if only a few atoms thick, and invisible to the eye, the catalytic reaction cannot occur and the engine will run poorly or not at all. Around ninety percent of all reported engine problems can be traced to contaminated fuel that coats the glow plug coil and prevents the plug from operating properly.

Many varieties of rubber will dissolve in glow fuel and quickly foul a glow plug coil. Use only silicone fuel tubing and plastic (polyethylene, polypropylene or nylon) containers to store or transfer fuel.

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**Note:**

**DO NOT USE RUBBER FUEL BULBS, SYRINGES WITH RUBBER PLUNGERS OR NEOPRENE FUEL LINES TO TRANSFER FUEL INTO YOUR HELICOPTER. RUBBER WILL CONTAMINATE YOUR FUEL AND FOUL YOUR GLOW PLUG.**

---

Certain brands of model engine fuel contain chemical additives (such as anti-rust compounds) that can foul glow plugs. Some engines will run on these fuels for a flight or two, but then lose power. Some engines will not start at all. Do not use fuels that contain chemical additives such as anti-rust compounds with your Norvel engine.

There is no practical way of cleaning a contaminated glow plug coil. Discard contaminated glow plugs when changing to a new fuel or after using rubber in the fuel system.

---

**Hint:**

Use the Lite Machines *Lil' Squeezer* fuel system to quickly fuel and de-fuel your helicopter. The *Lil' Squeezer* fuel system consists of a fuel storage bottle that protects your fuel from sunlight during storage, and a filtered transfer tube that will not contaminate your fuel with rubber byproducts.

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## Synthetic Oils

Some brands of fuel contain synthetic oils that break down at relatively low temperatures. During a hot, lean run, synthetic oil may not provide sufficient lubrication to the engine piston and cylinder, and the piston may seize inside the cylinder or otherwise damage the engine.

Do not use fuels containing only synthetic oil with your Norvel engines. Use fuels containing castor oil or castor/synthetic oil blends. For instance, if you like Morgan's brand fuels, do not use Morgan's *Cool Power* fuel with synthetic oil (the green stuff). Instead, use Morgan's *Omega* fuel with castor/synthetic oil blend (the pink stuff).

## Breaking-In a New Engine

All piston engines have a break-in period (from ten minutes to over an hour) in which they do not produce peak power. The piston and cylinder of Norvel engines are selectively matched at the factory to fit tightly at top-dead-center (where the piston is at the top of the cylinder). During break-in, the piston and cylinder wear together to form a perfect fit that will last the life of the engine.

To break-in your new Norvel engine, run it rich (where it runs slowly and unevenly) for two to three minutes before leaning it out. Then alternately run lean (where it just starts to speed up and run steadily) for two minutes and then rich for two minutes for a total of about 20 minutes or two tanks of fuel. This lean-rich break-in procedure not only wears the surfaces of the piston and cylinder, but also heats and cools the engine and relieves built-in stresses in the metal of the piston and cylinder.

You may break-in your new engine on a test stand or in your helicopter. Always use a Lite Machines heat sink on the engine in your helicopter. If you use an airplane style glow head without the heat sink, your engine will overheat and seize. **NEVER** run your engine a test stand without an airplane propeller. The propeller not only cools the engine, but produces drag which keeps the engine from over-speeding.

### Warning!

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**NEVER RUN A HELICOPTER ENGINE ON AN ENGINE STAND WITH ONLY THE CLUTCH FROM YOUR HELICOPTER OR WITHOUT A PROPELLER. THE CLUTCH SHOES CAN BE THROWN OFF AT HIGH SPEED AND CAUSE SERIOUS INJURIES AND PROPERTY DAMAGE.**

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## Engine Starting Summary

This section provides a short summary of proper engine starting procedures for your Lite Machines helicopter. For more detailed information, refer to the *Preferred Engine Starting Procedure* section of this Operator's Guide.

1. Fill the fuel tank with fuel.
2. Turn on your transmitter and receiver.
3. Open the engine needle valve 2-1/2 turns.
4. Connect your glow plug battery to the glow plug.
5. Start turning the engine with a Lite Machines high-speed electric starter.
6. While still turning the engine with the starter, hold your finger over the carburetor intake for one second to prime the engine (keep turning the engine with the electric starter).
7. Remove the electric starter from the engine every two seconds to see if it is running.
8. Repeat step 6 and 7 as required.

## Preferred Engine Starting Procedure

This section contains a detailed, step-by-step procedure for starting the Norvel engine in your Lite Machines helicopter. Since you will probably want to try flying your helicopter once the engine is running, you should first read the *Main Rotor Stability and Control* and *Learning to Fly* sections of this Operator's Guide. Starting the engine with a helper is strongly recommended. Priming and adjusting the engine are much easier with the aid of a friend.

1. Bring all necessary equipment with you to the flying field including hand tools like pliers and wrenches, Lite Machines electric starter and battery, and a supply of paper towels and spray cleaner.
2. Wear eye and hearing protection.

### Warning!

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**ALWAYS WEAR EYE AND HEARING PROTECTION, SUCH AS HIGH-IMPACT SAFETY GLASSES AND EAR-PLUGS, WHEN OPERATING YOUR ENGINE. ANYONE HELPING YOU SHOULD WEAR EYE AND HEARING PROTECTION AS WELL. PROPER EYEWEAR NOT ONLY HELPS PROTECT YOUR EYES FROM THE SPINNING ROTORS, BUT ALSO FROM OIL DROPLETS AND DEBRIS THROWN OUTWARD BY THE SPINNING ENGINE AND CLUTCH.**

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3. Fill the fuel tank to within 1/4" of the top with model engine fuel containing 15% to 25% nitromethane and castor oil or a castor/synthetic oil blend.

### Warning!

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**NEVER FUEL YOUR HELICOPTER WHILE THE GLOW-PLUG BATTERY IS CONNECTED TO THE ENGINE. SPARKS FROM THE ELECTRIC CONNECTION COULD START AN INVISIBLE FUEL FIRE.**

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4. Make sure your radio frequency is clear.

### Warning!

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Two radios cannot operate on the same frequency (channel) at the same time. If you turn on your transmitter, and it is on the same frequency (channel) as the transmitter of someone who is already flying, the flying aircraft will lose control and crash.

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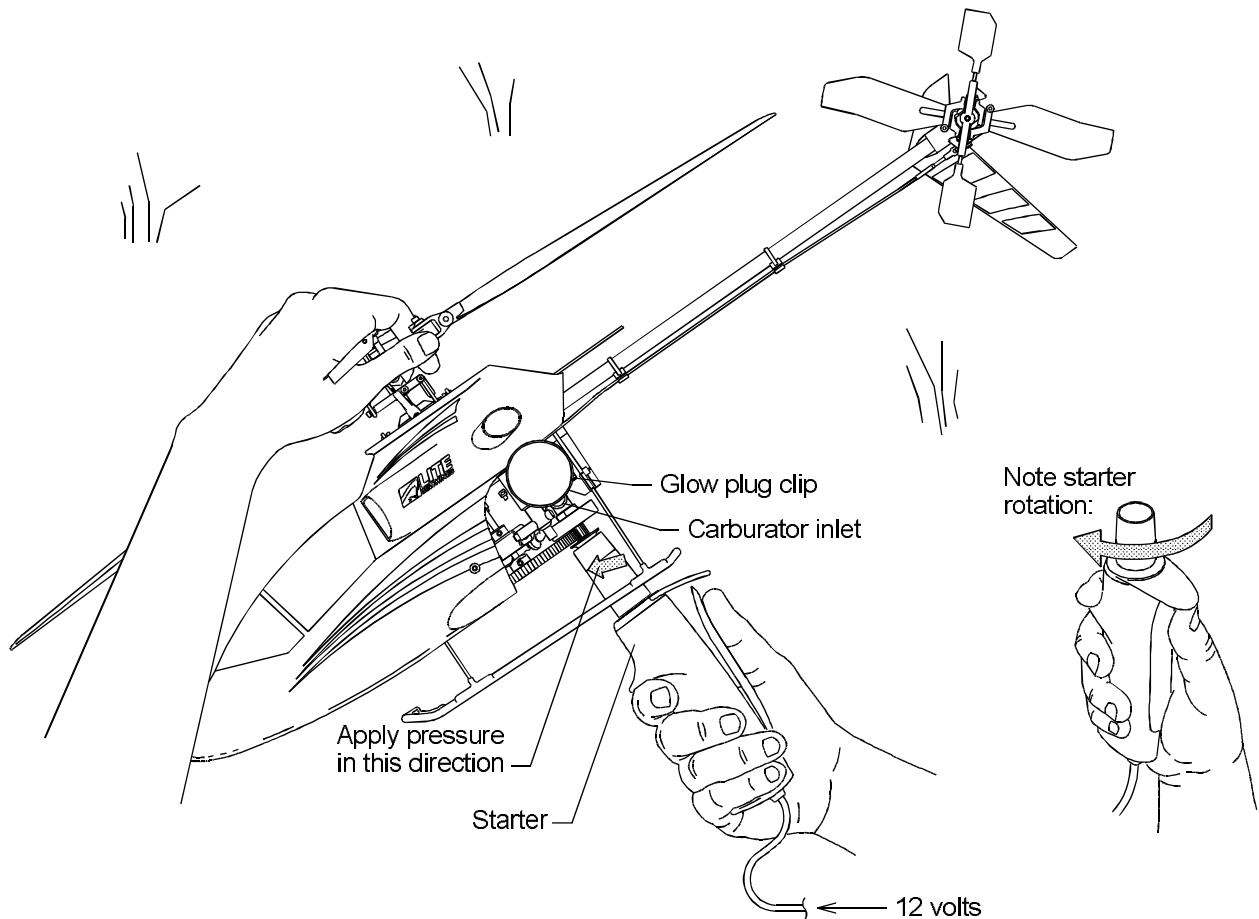
5. After you are sure that your frequency is clear, turn on the radio (transmitter first) and check the operation of all controls. If this is the first flight of the day, perform a radio range check. With the transmitter antenna fully collapsed, slowly walk away

from the model while moving one of the controls. You should get at least 50 feet away before losing signal (this distance varies with different radio equipment). Do not start your engine or fly if the radio fails the range check.

## Warning!

**NEVER RANGE CHECK WITH THE ENGINE RUNNING! THE ENGINE MAY GO TO FULL POWER AS YOU EXCEED THE OPERATING RANGE OF THE RADIO.**

6. Fully extend the transmitter antenna before starting the engine.
7. If starting the engine for the first time, carefully turn the needle valve clockwise with a small screwdriver until fully closed, then open it counter-clockwise 2 to 2-1/2 turns.
8. Connect your Lite Machines high-speed electric starter to a 12-volt starter battery. The starter should spin in the direction shown in Fig. 4-1. If not, reverse the starter wires on the battery.



**Figure 4-1.**



9. Connect the glow plug to a 1.2 volt battery or a hobby power panel.

**Note:**

Lite Machines *SpiraLite Speed* and Norvel *Freedom XL* glow plugs require 1.2 volts. The best way to power a Lite Machines or Norvel glow plug is with a DuBro *Kwik-Start* clip. Never wire the glow plug directly to 12 volts (like your car battery) or the plug will burn out.

10. Connect the glow plug clip to the glow plug on the engine as shown in Fig. 4-1 and Fig. 4-2.

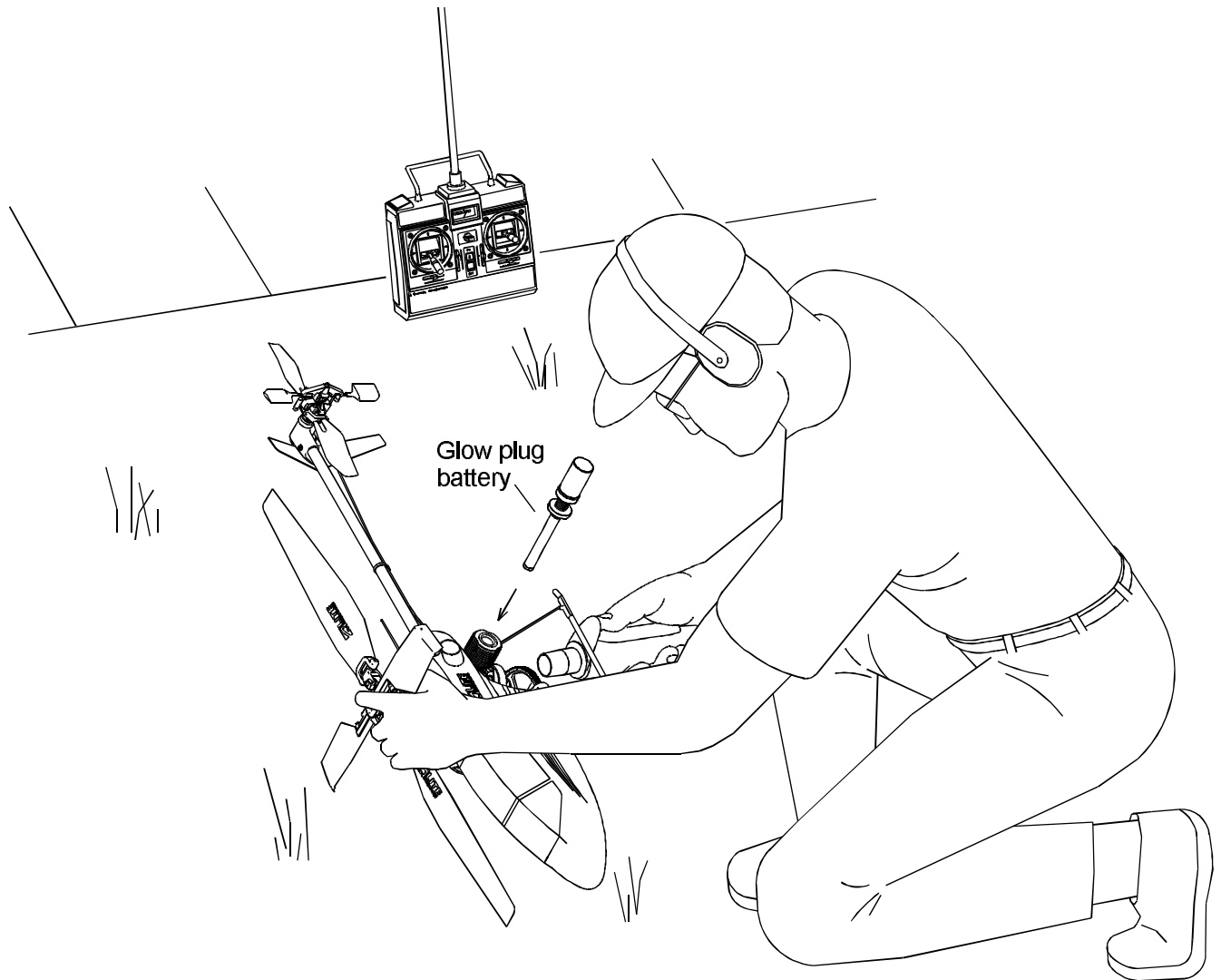


Figure 4-2.

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**Warning!**

**ALWAYS WEAR EYE AND HEARING PROTECTION.** Model engines throw out oil droplets when running. It is nearly impossible to avoid getting oil on you while starting the engine.

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12. Move the transmitter throttle stick (left stick) to about  $\frac{1}{2}$  throttle, and the throttle trim lever to full. Hold the rotor head with one hand, and tilt your helicopter on its side with the right skid on the ground as shown in Fig. 4-1 and Fig. 4-2.
13. Spin the engine with the electric starter. Push firmly, but not excessively on the starter cone as shown in Fig. 4-1.
14. The fuel line from the tank must be full of fuel before the engine will start. While you spin the engine with the starter, ask your helper to hold a finger over the carburetor inlet for one second. This will draw fuel from the tank into the engine. You may need to repeat this procedure several times before the engine will fire.

---

**Hint:**

If your engine is new it may not turn easily against compression. It will turn more easily after running for about 30 minutes.

---

15. If the starter slips on the starter cone, the piston may be hydraulically locked. Do not force it to turn or you could damage the engine. Remove the heat sink and glow plug and spin the engine with the electric starter for one second to clear the excess fuel from the cylinder and crankcase. Replace the glow plug and heat sink, and clean the oil off the starter cone and the rubber insert on the starter with a paper towel.
16. If the engine refuses to pop, remove the heat sink and glow plug, and connect the glow plug to the glow plug clip (be careful, it gets very hot). The entire coil should glow bright orange (not visible in direct sunlight). If it does not, the glow plug or glow plug clip may be bad, or the glow plug battery may need charging.

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**Hint:**

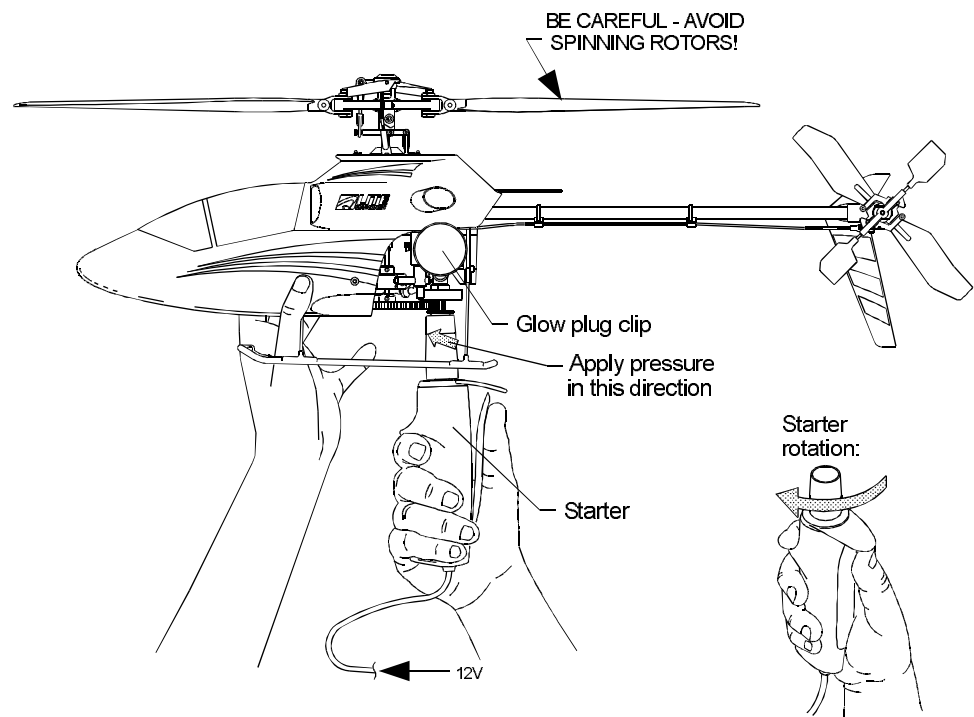
All glow plugs have a limited useful life. When you suspect that a glow plug is going bad, replace it with a new one. If engine performance improves, the old glow plug was bad.

---

17. When the engine starts, immediately lower the throttle so that the clutch shoes do not wear against the clutch bell. Be careful, if the throttle is set too high the clutch will engage and rotate the whole fuselage (and tail rotor) toward you.
18. Remove the glow plug clip, and place your helicopter on its skids on the ground so that the main rotor can rotate freely.

## Alternate Starting Method

Fig. 4-3 illustrates an alternate starting method requiring two people – one to hold and start the helicopter and another to hold and operate the transmitter. This starting method is illustrated for completeness and because the engine sometimes starts more easily when held vertically. This method is not preferred because of the proximity of the rotating rotor blades to the person holding the helicopter.



**Figure 4-3.**

Before starting the engine, make sure your helper knows how to operate the controls on the transmitter, and knows to never move the cyclic controls (right stick) while the rotors are turning. Hold your helicopter by the canopy and front landing gear struts as shown in Fig. 4-3 with the main rotor above and tilted away from you. Once the engine is running, lower the throttle and place the helicopter on the ground.

### Warning!

**THE CYCLIC CONTROLS ARE VERY POWERFUL. KEEP IN MIND THAT THE HELICOPTER COULD ROTATE OUT OF YOUR GRASP AND STRIKE YOUR HANDS, ARMS OR FACE. RAPIDLY ROTATING ROTOR BLADES CAN CAUSE SERIOUS INJURY.**

### Warning!

**NEVER, EVER ATTEMPT THE ALTERNATE STARTING METHOD WITH A LARGER HELICOPTER! THE ROTATING ROTOR BLADES ON A LARGE HELICOPTER CAN BE LETHAL!**

## Adjusting Fuel Mixture and Compression

This section describes a step-by-step procedure for adjusting fuel mixture and compression on Norvel engines.

1. Set your helicopter on the ground with the engine idling. Slide a heavy pole or wood plank from side to side over the landing gear skids and between the wire struts in order to weigh your helicopter to the ground. With the helicopter safely grounded, you can adjust the needle valve at full power. Slowly open the throttle. If the helicopter lifts into the air, place a heavier weight across the skids.
2. Move the throttle stick and throttle trim lever on the transmitter to full throttle.
3. Carefully reach under the rotor blades and slowly open (screw out) the needle valve until the engine runs roughly (four-strokes). This fuel/air mixture is too rich.

### Warning!

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**MOVE SLOWLY AND CAREFULLY ANY TIME YOU WORK NEAR THE ROTATING ROTOR BLADES! DO NOT TOUCH THE ROTATING ROTOR BLADES WITH YOUR HAND OR ARM! ALSO WATCH OUT FOR THE ROTATING TAIL ROTOR BLADES!**

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4. Slowly close (screw in) the needle valve. The engine will run faster and smoother, and the engine sound will increase in pitch. At some point you will hear it slow down again. This mixture setting is too lean. The optimum needle valve setting lies about half way between the rich and lean settings. It is best to operate with a slightly rich mixture since the engine will run cooler.
5. Open (screw out) the needle valve to the optimum point half way between the rich and lean settings.
6. Close the throttle (throttle trim is still high). The engine should idle smoothly, and slowly enough that you can hold the main rotor without feeling much clutch drag. If the engine runs too fast, try reducing throttle trim slightly. If it stops suddenly, the compression may be too high - add another copper washer under the glow plug and adjust the needle valve. **BE CAREFUL, THE HEAT SINK IS HOT!**

### Hint:

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Never hold the rotor head while tightening or loosening the heat sink, because you could bend the main shaft. Instead, hold the crutch near the tail boom

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7. Open the throttle to full, and listen closely to the engine sound. The engine should smoothly and rapidly increase speed to a maximum. If it sputters and increases speed slowly or four-strokes (runs rough) it may be slightly rich, so screw **IN** the needle valve slightly. If it reaches top speed and then sags or "warbles" it may be lean, so screw **OUT** the needle valve slightly.

8. If the needle valve seems to be adjusted correctly but the engine does not produce much power, it may not yet be broken-in or the compression may be set too low. Try removing a washer from under the glow plug and readjusting the needle valve. Handle glow plug washers carefully; they bend easily. Discard damaged washers.
9. After the needle valve and compression are set, they need not be adjusted for the rest of the day unless the temperature (air density) changes. If it gets cooler, adjust the needle valve out (rich) slightly.

## Inspecting *SpiraLite Speed* Glow Plugs

This section refers to the operation of *SpiraLite Speed* glow plugs, and not to Norvel *Freedom XL* glow plugs.

To start your Norvel engine, the coil in your *SpiraLite Speed* glow plug must glow bright orange. To test a glow plug, connect it to a glow plug battery with a glow plug clip, and cup your hands around the plug to keep it out of direct sunlight. **BE CAREFUL, THE PLUG WILL GET HOT QUICKLY.** The entire coil should glow bright orange. If no part of the coil glows bright orange, disconnect the glow plug clip and check your battery and wire connections.

If only a portion of the coil glows orange, then the coil may be touching itself and creating an electrical short circuit, or touching the glass insulation sealing the top of the plug and losing heat. In either case, disconnect the glow plug clip and **CAREFULLY** separate the loops of the coil from each other, and lift the coil slightly away from the glass insulation with the tip of a hobby knife as shown in Fig. 4-4. Test the glow plug again before installing it in your engine.

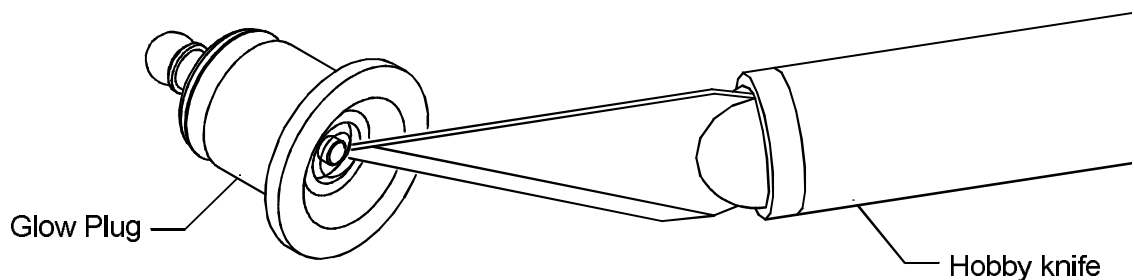


Figure 4-4.

## Electric Starter Effect on Glow Plug

Norvel engines usually start easily. On-going difficulty with engine starting is sometimes a sign of a field-equipment problem.

Many fliers have a field box with a small 5 Ah motorcycle battery connected to a power panel which powers the glow plug and electric starter motor. Common high-torque electric starters designed to start .40 and .60 sized engines are too slow to start small engines and sometimes draw too much current from the field box battery.

Even though a glow plug may appear to glow orange (hot) when connected to the field box battery by itself, it may cool substantially when an electric starter is operated. This means that the glow plug will stop working just as the starter motor begins to spin the engine, so the engine may not start. The plug will heat up again when the starter motor is turned off, making it appear as though the plug is working properly.

To check for this problem, plug a glow plug clip and a standard electric starter into a power panel. Connect the glow plug clip to a glow plug, and cup your hands around the plug to keep it out of direct sunlight. The coil should glow bright orange. Be careful, the plug will get hot quickly.

Turn on the electric starter. If the field box battery is small, old, or low on charge, the plug coil will cool and stop glowing. Turn off the starter and the plug will again glow orange. Also, try operating the starter in one second pulses. Notice that the glow plug remains hot longer if the starter is pulsed.



# Main Rotor Stability and Control

To fly properly and produce maximum lift, the rotor blades of your helicopter must be adjusted correctly. This section contains information on setting up and tracking the main rotor blades, and understanding helicopter stability and flight performance. Refer to the *How Helicopters Work* section of this Operator's Guide for more information on main rotor systems.

## Rotor Blade Designations

Lite Machines rotor blades each have a blade number that describes the blade design and size. Series 1 blades, which are standard on *Model 110* and earlier helicopters, are not marked. Blades having different numbers are incompatible with each other, so do not use two blades with different numbers on the same rotor head.

Blade designations have three parts: the series number, length and tip pitch. For example, the blade designation S2 13 x 0 is read "series 2, 13 inch length, zero degrees tip pitch". Blade length is measured from the center of the flapping bolt hole to the tip of the main rotor blade or from the center of the rotor shaft to the tip of the tail rotor blade. Blade pitch is relative to the blade grip.

### Warning!

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Series 2 main rotor blades are susceptible to damage by solvents and other chemicals. **DO NOT USE SOLVENTS, SUCH AS ACETONE, TO CLEAN THE MAIN ROTOR BLADES! BLADES CLEANED WITH SOLVENTS CAN FAIL WITHOUT WARNING WHEN ROTATING AT HIGH SPEED CAUSING SERIOUS INJURIES.** Use only soap or glass cleaners that are safe for plastic eye glass lenses.

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### Warning!

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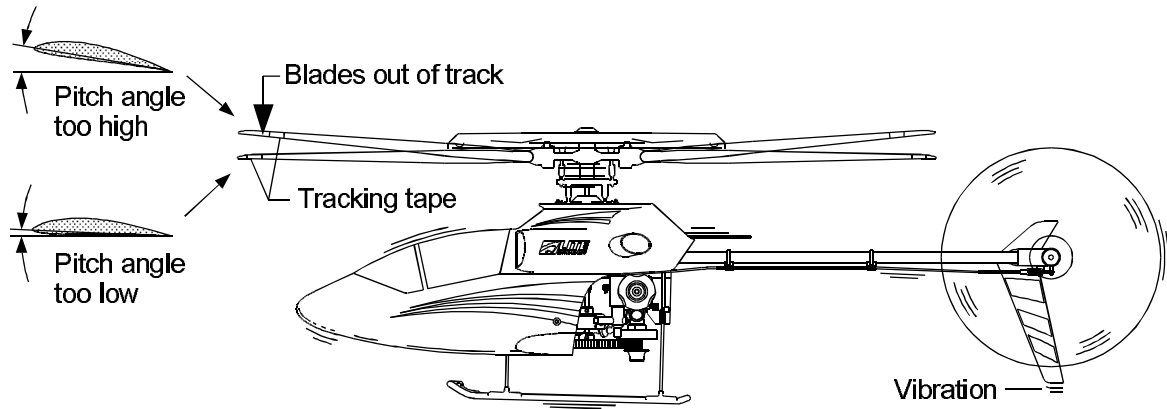
**DO NOT ATTEMPT TO REPAIR DAMAGED ROTOR BLADES. REPAIRED BLADES CAN FAIL WITHOUT WARNING WHEN ROTATING AT HIGH SPEED AND CAUSE SERIOUS INJURIES.**

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## Blade Tracking

The main rotor blades on your helicopter must operate at the same pitch angle. If they do not, one blade will fly higher than the other causing an imbalance and vibration. This vibration absorbs engine power and can damage the helicopter.

Before adjusting blade pitch, your first need to know which blade is pitched high and which is pitched low. To do this, stick a 1/4" (6mm) wide piece of highly visible tape (tracking tape) near the tip of one blade and another about an inch (25mm) from the tip of the other blade. Don't worry about causing an imbalance; you will remove the tape when the blades are tracked.

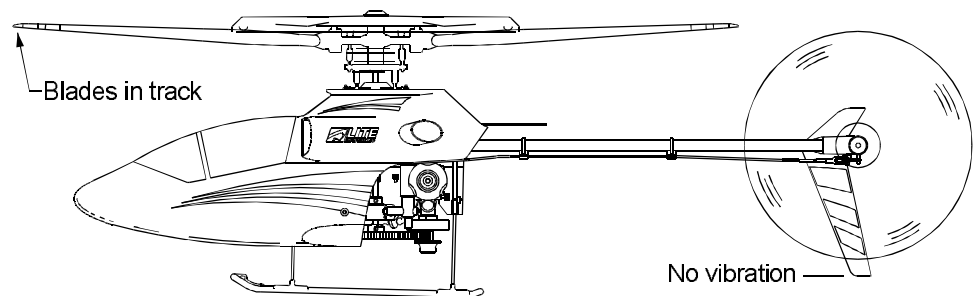


**Figure 5-1.**

Start the engine as outlined in the *Preferred Engine Starting Procedure* section of this Operator's Guide. Once the engine is running properly, open the throttle until your helicopter is just about to lift off (about half throttle). Look at the tips of the rotating rotor blades (but never place your eyes or face in-line with the blades). If you see two blade images as shown in Fig. 5-1, then the blades are out of track (one blade is flying higher than the other).

**Note:**

Before starting the engine, make sure that all radio and starting equipment batteries are completely charged as per the manufacturer's instructions. If the radio batteries die while you are flying, you will lose control and crash.



**Figure 5-2.**

As the main rotor spins, look at the tracking tape and note which blade is flying higher. Stop the rotor and adjust the length of the two mixing-arm/swashplate pushrods to increase the pitch of the low blade and decrease the pitch of the high blade. Remember that if you decrease the length of one of the pushrods, you must increase the length of the opposite one by the same amount to keep the linkages from binding. When the blades track properly as shown in Fig. 5-2, remove the tracking tape.

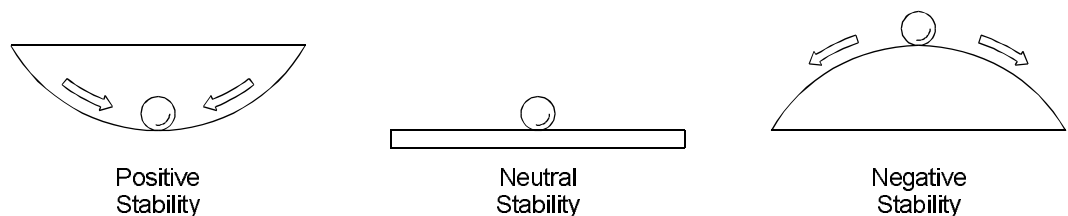


## Dynamic Balancing

If the main rotor blades are tracking properly, but the helicopter still vibrates noticeably, the main rotor may not be properly balanced. To dynamically balance the main rotor without removing it from the helicopter, stick a small piece of blade balancing tape to one of the main rotor blades and run the main rotor at flight speed. If the vibration level decreases, the extra weight of the trim tape is improving the balance. If the vibration increases then remove the tape, stick it to the opposite blade and spin the main rotor again. Try different sizes of trim tape until you find one that minimizes the vibration. Repeat this procedure for the *Arlton Subrotor* stabilizer.

## Helicopter Stability

Helicopters by their nature are not positively stable. At best, they are neutrally stable. The concepts of positive stability and neutral stability can be illustrated by placing marbles in a bowl and on a table top as shown in Fig. 5-3.



**Figure 5-3.**

If you nudge the marble in the bowl with your finger, it will roll back and forth and finally come to rest where it started in the center of the bowl. This is positive stability; the marble always ends up where it started. If, on the other hand, you push the marble on the table, it will continue to roll until you stop it, and will sit still until you push it again. This is neutral stability; the marble stays put until pushed, and keeps moving until stopped.

Helicopters act like the marble on the table. When correctly trimmed they tend to remain in one spot until moved, and tend to keep moving until stopped. Unlike the marble, however, helicopters vibrate and fly in air that is always swirling and rolling. As a result they do not stay in one place for very long, and require constant small control inputs to hover over a spot on the ground. The marble on the table would act more like a helicopter if you shook the table and tilted it back and forth. You would have to constantly push the marble from different directions to keep it in one spot.

## Adjusting Main Rotor Blade Pitch

Main rotor blade pitch on Lite Machines helicopters is adjusted by interchanging the blade grips that hold the blades to the rotor head. Blade grips are available in even numbered two-degree increments from two degrees to six degrees and are called two-grips, four-grips and six-grips. Odd-numbered grips are not available.

Six-grips increase natural blade pitch by six degrees, and are identified by six raised dots on the top of the grips. To change blade pitch from six degrees to five degrees, remove **ONE** six-grip and install a four-grip (four raised dots). After adjusting the mixing-arm/swashplate pushrods so that the blades have equal pitch (that is, after re-tracking the blades), each blade will be pitched five degrees. Note that re-tracking the blades usually requires two complete turns of the pushrod ball-links for a one degree change in blade pitch.

### Warning!

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Be careful not to reduce blade pitch so much that the main rotor exceeds its maximum rated speed since excessive speed could damage the main rotor or engine.

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## Stability and Climb Performance

Helicopter flight stability and control power is affected by the rotational speed of the main rotor. At high rotor speeds, the main rotor blades generate high gyroscopic forces that stabilize the main rotor, and minimize the effects of disturbances such as wind gusts. The rotor blades can also generate the high aerodynamic (air) forces needed to forcefully push the helicopter around when the pilot moves the controls.

On fixed-pitch helicopters, helicopter weight and the pitch of the main rotor blades determines the operating speed of the main rotor, and directly affect stability, control power and climb performance. High blade pitch generally improves climb performance, but reduces stability and control power in hover.

This is because rotor blades operating at a high pitch angle produce lift at a relatively low rotor speed. They do not generate the gyroscopic forces needed for solid stability, or the aerodynamic forces needed for snappy control. Low blade pitch, on the other hand, increases rotor speed and stability but reduces climb performance.

The main rotors on Lite Machines helicopters are designed to generate high lift with very little engine power. High lift is required to fly on hot days and at high elevations where air density is low. When flying at low elevations (especially near sea level where air density is high) and with high blade pitch, some helicopters may leave the ground without adequate rotor speed for acceptable stability and control power.

The usual solution to this problem is to add weight in order to increase rotor speed. Generally, main rotor blade pitch should be set to the highest value that provides acceptable stability (usually five degrees when flying near sea level, and six degrees at higher elevations).

Big, heavy things (like luxury cars, or larger helicopters) tend to move more slowly and smoothly than small, light things. This is called the “Cadillac” effect (a Cadillac being a big luxury car). Small light helicopters respond to air disturbances more quickly than larger helicopters, and bounce around more in the wind. The *Model 110* helicopter is more like a compact car than a luxury car.

Adding one to five ounces [28g to 142g] of weight to a Lite Machines gas-powered helicopter will significantly improve its flying qualities, especially in windy conditions. Although it may seem odd to purposefully add weight to a flying machine, the additional weight requires a higher rotor speed to lift off the ground. This high rotor speed generates the stability and control power needed to fly in gusting winds.

If, after adjusting blade pitch and weight, you would like more control power, move the Z-links in the rotor head to the alternate (inner-most) holes on the pitch plate and mixing arms. This will reduce the stabilizing input of the *Arlton Subrotor* stabilizer and increase the control input of the swashplate to the main rotors (thereby decreasing stability and increasing control power).



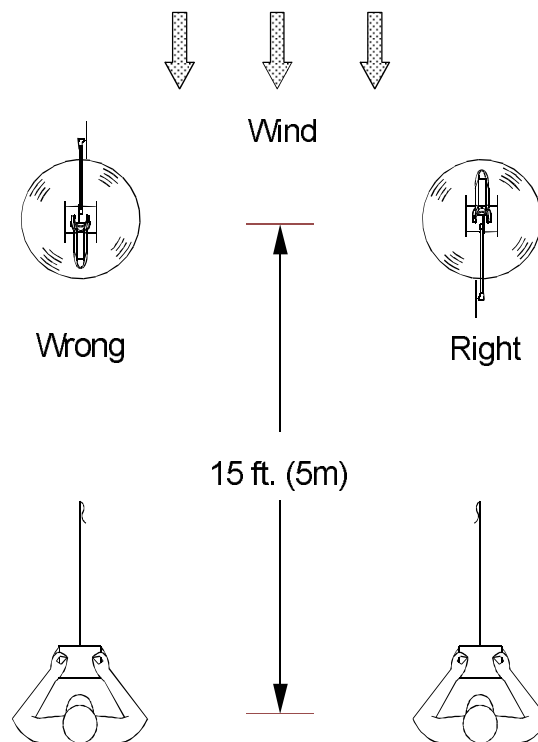
# Learning to Fly

This section describes a three step process for learning to fly your Lite Machines helicopter. Although it is possible to learn on your own, try to find an experienced helicopter pilot to help. An experienced pilot can start and tune your engine, trim the controls, track the rotor blades and copilot your helicopter while you are learning. Computerized flight simulators are also an excellent way to gain flight experience without risking your model.

Model flying clubs are a good source of information, and many have flight instructors. Note, however, that advice from modelers can be highly subjective, so talk to several individuals and refer frequently to this *Operator's Guide*. Also, join the Academy of Model Aeronautics (AMA). The AMA provides services to modelers and liability insurance to cover accidents. Many flying fields require an AMA license to fly.

## Getting Started

Learn to fly on days with little or no wind. If there is a slight breeze, fly with your helicopter pointed into the wind as shown in Fig. 6-1. It will tend to “weather vane” (point into the wind) making it easier to fly.



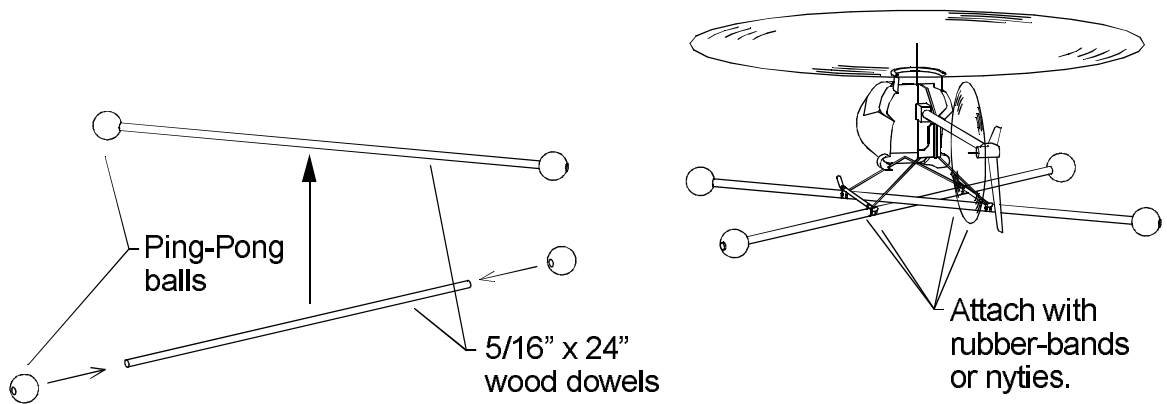
**Figure 6-1.**

Fly your helicopter in open areas outdoors away from people and property such as buildings and cars. When learning to hover, the best flying sites are clean, smooth paved surfaces. While not as soft as grass, paved surfaces allow the model to skid around without leaving the ground. A drawback of paved surfaces is the abundance of abrasive grit kicked up by the rotor wash that can be ingested by your helicopter engine and ground into the gears. If you sweep a small area clean with a broom your helicopter will stay cleaner and last longer.

After mastering the basics of hovering flight, take off from concrete and fly over long grass. Long grass is much more forgiving than concrete for the occasional unintended landing.

## Training Gear

Use training gear while learning to hover. Training gear consists of two light wooden dowel rods attached to the landing gear of your helicopter as shown in Fig. 6-2. Training gear helps prevent tip-overs, and also slows down control response. Cross two 5/16" x 24" (8mm x 61cm) wood rods to form an "X", and attach these rods with rubber bands or nylon ties to the base of each landing gear strut. Glue Ping-Pong balls to the ends of the rods with thick CA glue to prevent the dowels from catching on the ground.



**Figure 6-2.**

**Note:**

If the rods are too long or too heavy your helicopter will appear unstable in flight because heavy rods tend to swing under the fuselage on the thin wire landing gear. If this happens, reduce the size or length of the rods.

## Step 1: Learn the Left Stick

The following describes a step-by-step process for learning to fly your Lite Machines helicopter. The process consist of driving the helicopter on the ground using just the left control stick on the transmitter until your control actions become unconscious and automatic. After mastering the left stick to steer, you learn the right stick to hover.

### Hint:

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Are your fingers comfortable on the transmitter control sticks? Stick length and centering tension are adjustable on most transmitters.

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Place your helicopter on a paved surface with the nose pointing into the wind, and the engine adjusted and idling. Stand about 15 ft (5m) behind the model, and slightly to the left or right (review Fig. 6-1). If you have an electric helicopter, plug the motor speed controller into the battery, and arm the speed controller.

Slowly open the throttle (move the left stick forward) to increase rotor speed until the model is light on the skids, but not actually flying. Move all controls to see if they work properly. Moving the left stick (tail rotor control) to the left and right should cause the **NOSE** to turn left and right. Moving the right stick (cyclic control) should cause the main rotor to tilt.

Increase the throttle (left stick) slightly and tilt the main rotor forward to pull the helicopter along the ground. Steer the **NOSE** with the left stick as the model moves forward. Do not look at the tail when steering your helicopter.

Drive around without actually leaving the ground until you have mastered steering with your left hand. Note that the tail rotor control appears to operate backwards when the helicopter is pointed towards you.

## Step 2: Practice Small Hops

While concentrating on the left stick, slowly open the throttle until your helicopter rises into the air. Pull the left stick back gradually to slow the engine and return to the ground. Repeat this step until you are accustomed to the throttle control. While practicing these hops, notice that the nose tends to turn to the left or the right as the model lifts into the air. Move the left stick in the opposite direction to compensate.

Remember to concentrate on the **NOSE** when using the left stick to turn. Do not look at the tail rotor. If the nose rotates to the left, push the stick to the right, and vice-versa. The objective is to keep the **NOSE** pointed away from you. Learning the right stick later will be nearly impossible if the nose turns toward you.

If the nose turns in the same direction on every hop, adjust the trim lever under the left stick to neutralize the turn. You can also adjust the length of the tail rotor pushrod by screwing the clevis in or out a few turns (if the nose turns left, shorten the pushrod; if right, lengthen it). In either case you are changing the pitch of the tail rotor blades slightly to neutralize the turn.

While learning the left stick, it is sometimes helpful to have an experienced flyer control the right stick (this requires a skilled pilot, since beginners often allow the model to turn nose-in). Agree ahead of time who does what in case things get out of control. If your helper on the right stick becomes disoriented, he should tell you immediately, in which case you should lower the throttle and land as quickly as possible.

If no one is available to help with the right stick while you concentrate on the left stick, allow your helicopter to wander a few feet during each hop. If it drifts or tilts in a particular direction on every hop, adjust the appropriate trim levers next to the right stick in the opposite direction.

For example, if it always tilts to the right, move the trim lever below the right stick to the left. You can also adjust the length of the servo pushrods controlling the swashplate. In either case, tilt the swashplate **OPPOSITE** to the direction of drift. Remember that it is impossible to trim any helicopter to sit still in the air. All helicopters require constant control inputs from the pilot to maintain a stationary hover.

### Step 3: Learn the Right Stick

After mastering altitude and heading control with the left stick, increase the throttle until your helicopter is at least three feet off the ground (where the air is less turbulent), and use the right stick to hover over a spot. It will be difficult at first, but try to keep the model within a small area. If you become disoriented, reduce the throttle and let the model settle to the ground. Resist all temptations to “punch” the throttle to full power and climb higher than three feet (you won’t know how to get down).

Keep the nose pointed away from you at all times. When the nose is pointing toward you (i.e. when you are flying “nose-in”), three of the four controls (fore/aft cyclic, left/right cyclic and tail rotor) are reversed. Nose-in hovering is difficult for beginners, and is typically not attempted without considerable experience.

When hovering, concentrate on the **TILT** of the main rotor disk (the circle made by the rotating rotor blades) and not on the motion of the helicopter body. The **TILT** of the main rotor controls the **MOTION** of the body. If you concentrate on the motion of the body, your control inputs will be slightly behind the tilt of the main rotor, and you will not be able to hold a steady hover.

#### Warning!

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**WHEN LEARNING TO HOVER, NEVER FLY CLOSER THAN 15 FEET (5 METERS) TO YOURSELF OR ANYTHING ELSE, OR HIGHER THAN ABOUT 3 FEET (1 METER). YOU COULD LOSE CONTROL AND CRASH CAUSING SERIOUS INJURY OR PROPERTY DAMAGE.**

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## Main Rotor Controls

You will notice a slight time lag between right stick control inputs and the resulting motions of the model as illustrated by Fig. 6-3. Frame 1 shows a helicopter hovering with the controls neutralized. In Frame 2, a control input tilts the helicopter to the left producing a small sideward thrust. Note that the helicopter tilts immediately with the control. In Frame 3, the controls are neutralized and the helicopter starts moving sideways. In Frame 4, with the controls still neutralized, the helicopter is moving rapidly.

It takes time to accelerate a helicopter after the main rotor tilts. Move the right stick in the desired direction just long enough to tilt the main rotor, then bring the stick back to neutral. Be patient, and allow the model to accelerate slowly. If you hold the stick too long, the model will tilt too far, accelerate very quickly and possibly get away from you.

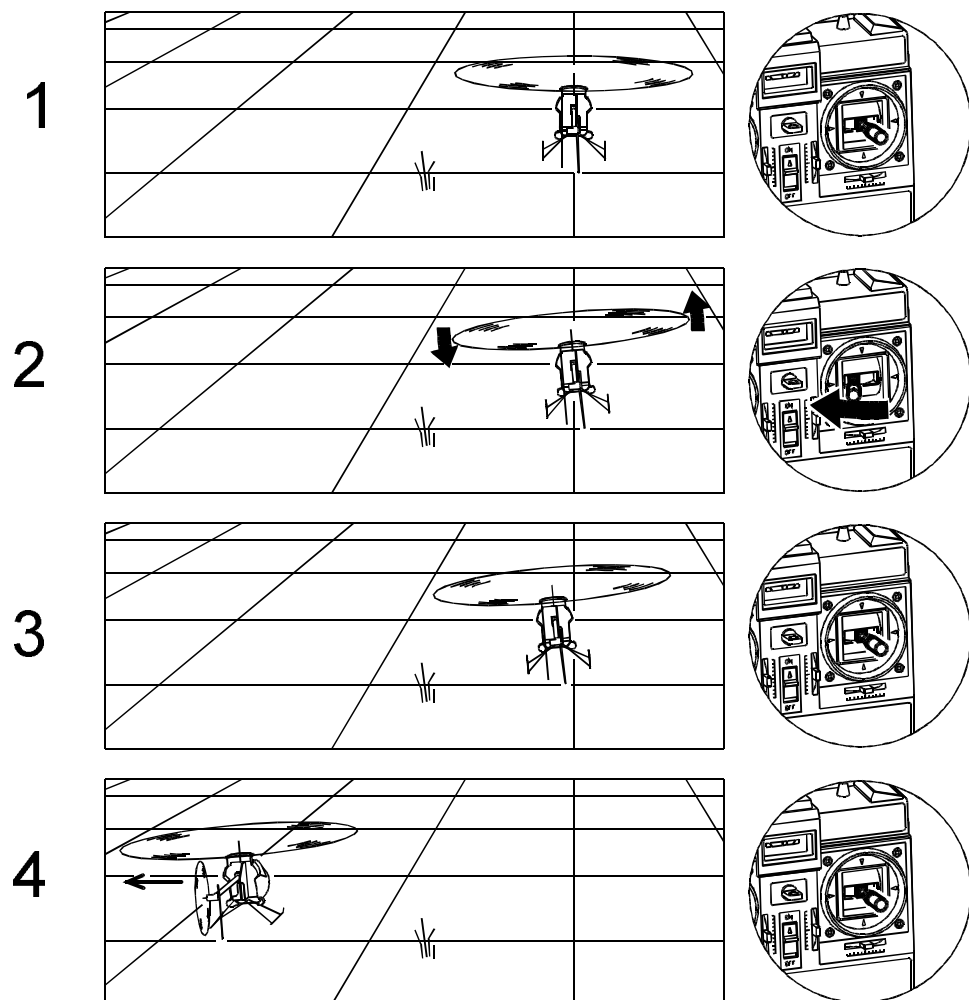
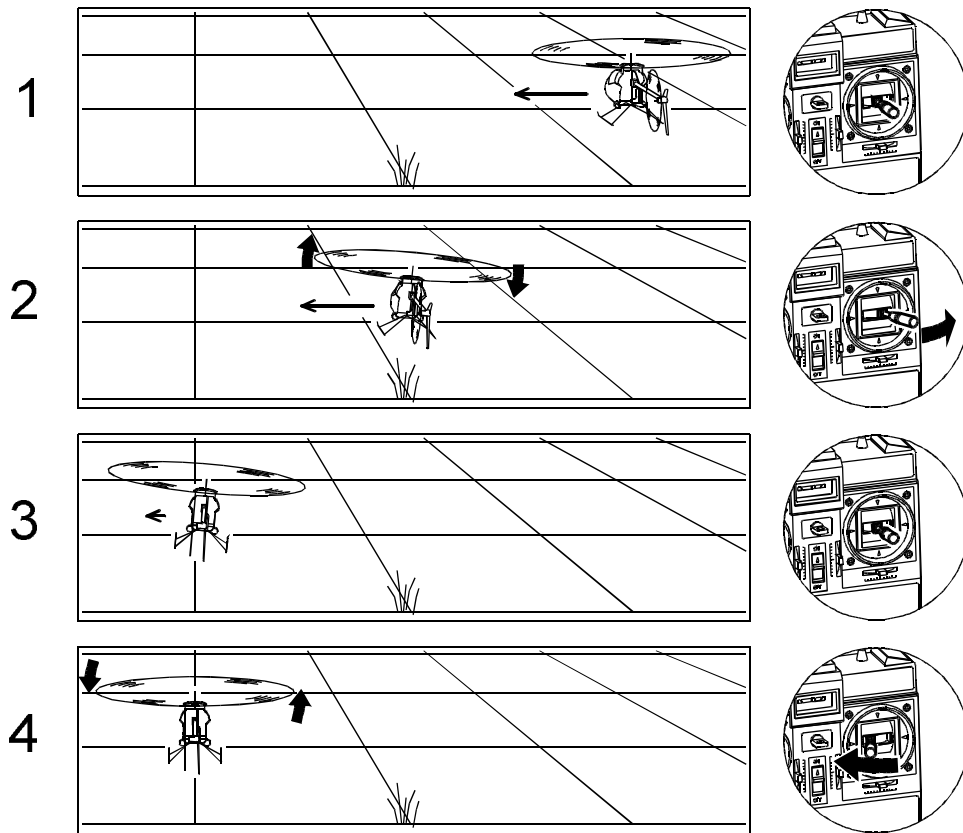


Figure 6-3.





**Figure 6-4.**

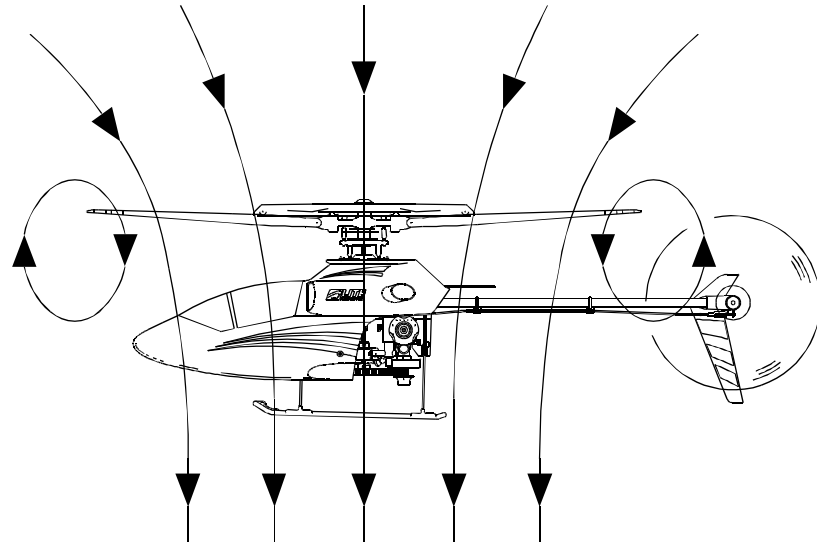
The same technique used to start a helicopter moving is used to stop. In Frame 1 of Fig. 6-4, a helicopter is moving sideways with controls neutralized. In Frame 2, a control input immediately tilts the helicopter to the right creating a small sideways thrust. Frame 3 shows the controls neutralized, and the helicopter slowing to a stop. In Frame 4, the helicopter has stopped, and a control input tilts it back to level and into a steady hover.

As you practice hovering, do not become discouraged if you are not immediately successful. Hovering a helicopter is one of the most difficult piloting skills to learn, and **NOBODY** learns to fly a model helicopter without crashing several times. Most people require several hours of practice before they can consistently hover over a spot. Flying a model helicopter is very challenging, and as a consequence, quite rewarding when you finally get the hang of it.

**Hint:**

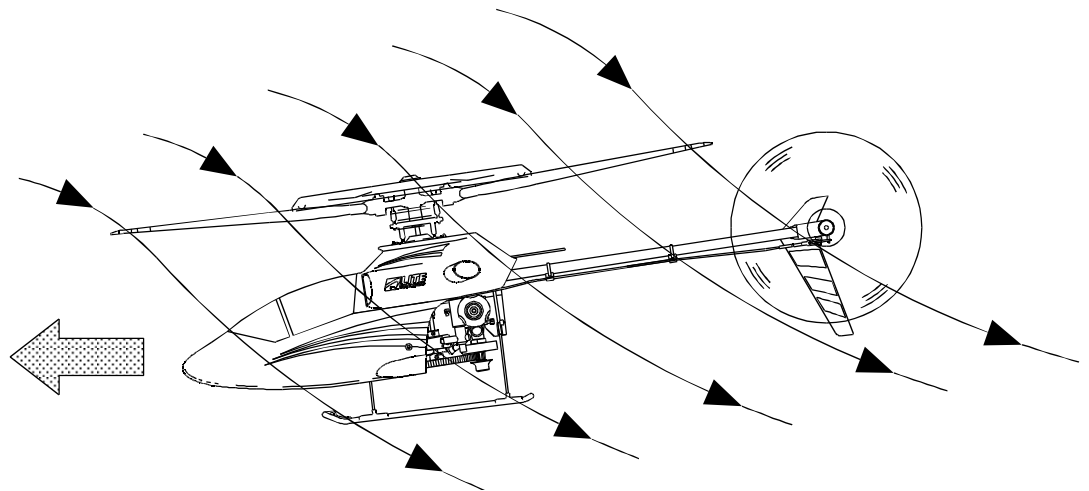
Spectators never really know what you are trying to do when you are flying your helicopter even when you miss your intended landing spot by fifty feet (15 m). If you wish to impress people, never tell them what you are trying to do, and they will assume you have everything under control.

## Forward Flight and Translational Lift



**Figure 6-5.**

When a helicopter is hovering in still air, the air flowing down through the main rotor (called the “down-wash”) tends to circle around to the top of the rotor and flow through again as illustrated in Fig. 6-5.



**Figure 6-6.**

As the helicopter starts moving forward it moves into cleaner, undisturbed air as illustrated by Fig. 6-6. The main rotor is more efficient in the undisturbed air, and produces more lift for the same amount of engine power. The increased lift causes the helicopter to climb.

This effect is called “translational lift” because the extra lift is generated as the helicopter translates (moves forward) through the air. Translational lift affects both model and full-size, man carrying helicopters. Some early, underpowered full-size helicopters could not climb above about twenty feet without moving forward to gain translational lift.

Even when a helicopter appears to be hovering in one spot, wind gusts can blow away the rotor down-wash and generate translational lift. The increased lift will cause the helicopter to climb. When the wind stops, the helicopter will suddenly fall. Piloting a helicopter in windy conditions can be difficult, and requires continuous throttle control inputs as the wind speed changes.

Tail rotors are also affected by translational lift. Forward motion and wind gusts cause the tail rotor to generate more lift and turn the helicopter. Windy conditions therefore require both throttle and tail rotor control inputs in order to maintain a constant altitude and heading.

Translational lift is much easier to control when the main rotor and tail rotor are turning at high speed because the speed of the down-wash is much greater than the speed of the oncoming wind. To increase rotor speed, refer to the *Stability, Control Power and Climb Performance* section of this Operator’s Guide.

### Circles

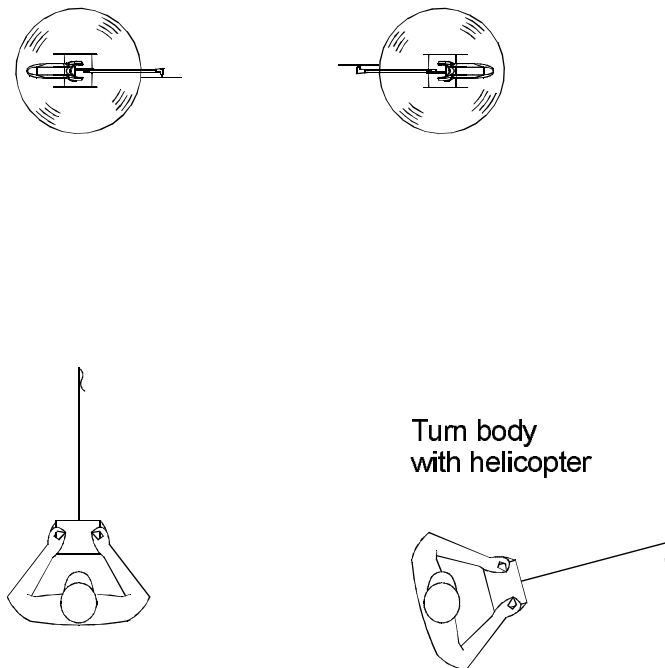
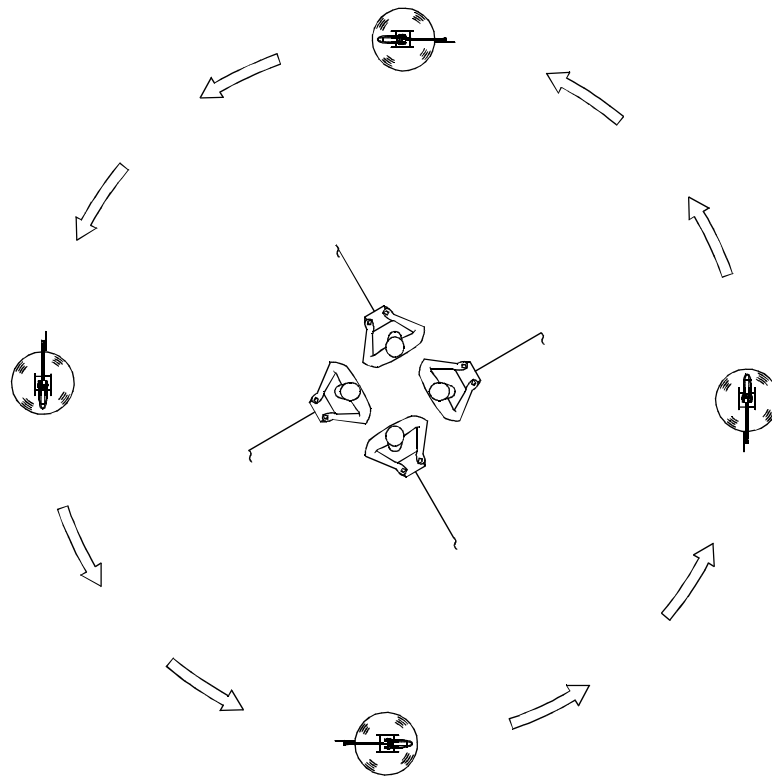


Figure 6-7.

Flying circles is a good way to prepare for forward flight. First practice hovering with the model turned sideways. It helps to turn your whole body with the model as shown in Fig. 6-7. Next, try flying circles around yourself as shown in Fig. 6-8. Practice both left and right circles. Concentrate on maintaining constant altitude (about 4ft or 1.2m) and distance (at least 15ft or 5m) at first. As you gain experience, fly larger circles at higher altitudes (do this in a big, open field away from people and obstructions).



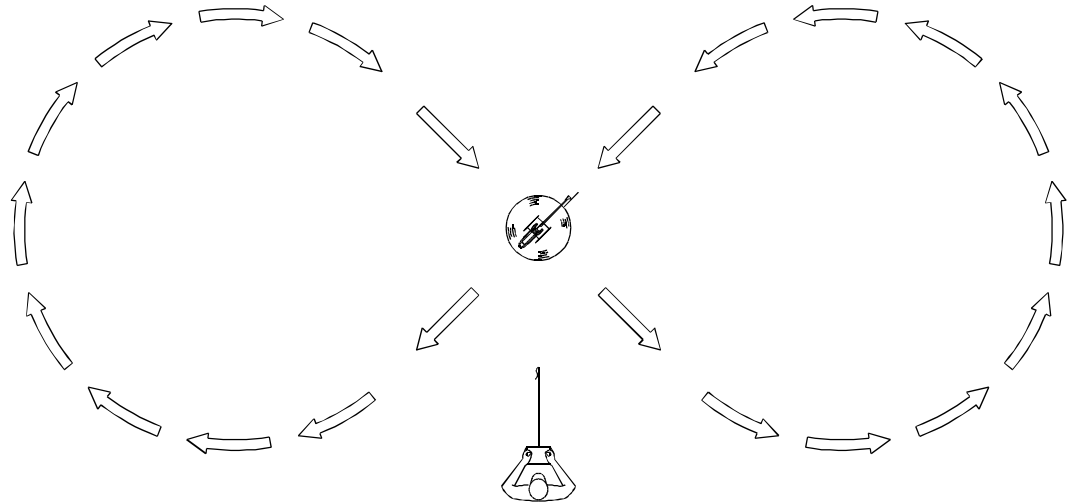
**Figure 6-8.**

Circles teach you how to control altitude and heading with the left stick, and speed and position with the right stick. Notice that speed and altitude are related. As the model picks up speed, it gains altitude (due to translational lift). Note too that the tail rotor produces translational lift, so you will have to hold right tail rotor control when the model starts moving forward. You will also discover that forward cyclic control is required to maintain forward speed (in this regard flying a helicopter in forward flight differs from flying an airplane).

Once you are comfortable flying circles around yourself to the left and right, try reversing direction at the end of each circle (turn away from yourself to avoid flying nose-in). Circle in one direction at an altitude of 10 to 20 feet (3m to 6m), then turn away and fly the reverse circle.

## Figure 8's and Nose-In Hovering

Having conquered hovering and circles, you have most of the basic flight skills needed for forward flight. The final skill to master is nose-in hovering. When the nose of the model is pointing toward you, the left/right and fore/aft controls appear to operate backwards. Your radio is still operating properly, but your frame of reference is reversed from that of the model.



**Figure 6-9.**

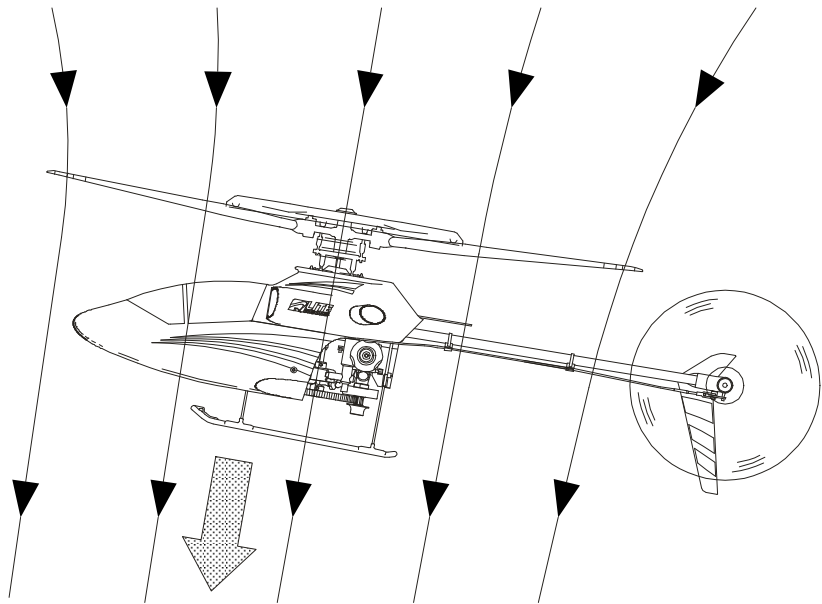
To prepare for nose-in hovering, practice flying figure 8's around yourself as illustrated in Fig. 6-9. Start by flying a right-hand circle. At some point, reverse the circle by turning to the left. As the model passes in front of you, you will fly nose-in for a few seconds. This is long enough to experience nose-in flight, but short enough to avoid becoming disoriented.

Practice both left-hand and right-hand figure 8's. After mastering figure 8's, try hovering nose-in (with the nose pointed directly at yourself). Two new rules will make this much easier.

The first rule for hovering nose-in is to steer the helicopter by concentrating on whatever part is furthest away from you, not just the nose. For instance, if the nose is furthest away concentrate on the nose and your left stick will steer the nose. If the tail is furthest away concentrate on the tail and your left stick will steer the tail.

The second rule for hovering nose-in is to push the cyclic stick toward the low blade in order to level the main rotor. For instance, if the main rotor tilts to the left, push the cyclic stick to the left and vice versa.

## Descending from Altitude



**Figure 6-10.**

If a helicopter descends straight down in still air, it will likely fly into its own down-wash as illustrated in Fig. 6-10. This is like flying into a strong downdraft and the helicopter will drop rapidly even at full power.

The technical term for this situation is “descending vortex-ring state”. Pilots of full-size helicopters refer to it as “settling with power” (although it is very unsettling to most pilots). If you are ever caught in this situation, immediately fly forward or sideways to exit the down-wash or you will soon hit the ground.

Another way to avoid settling with power is to fly in circles during descents. It is easier to judge forward speed when viewing the model from the side while it is circling rather than from the front when it is coming straight at you.

When descending from altitude, you will notice that substantial forward cyclic pressure is required to maintain speed in a descent. This is due to the decreased effectiveness of the cyclic controls as rotor speed is reduced (a characteristic of all fixed-pitch rotor systems).

## Landing

Landings can be a source of tail boom strikes for beginning helicopter pilots. Helicopter flyers with airplane experience sometimes unconsciously pull back on the fore-aft cyclic stick as their helicopter nears the ground as though they are controlling the elevator on an airplane. This tilts the helicopter backward.

When the helicopter lands, the fuselage rotates forward parallel to the ground, but the main rotor blades continue their downward and backward motion and eventually strike the tail boom. To avoid this problem, apply forward cyclic pressure as your helicopter touches the ground. Forward cyclic also tends to keep the tail rotor high when landing in tall grass.

Lite Machines helicopters tend to rotate to the left when you suddenly drop the throttle after landing. By suddenly lowering the throttle you remove the engine torque driving the main rotor, but the main rotor and tail rotor are still turning at high speed. The thrust force produced by the tail rotor pushes the nose of the helicopter to the left. To make your landings more precise, reduce the throttle slowly after touch-down, or apply right tail rotor control when reducing throttle. For more information on tail swing, refer to the *Tail Swing and Revo Mix* section of this Operator's Guide.

## Piezo Gyro Stabilizers

The tail rotor of most helicopters is connected directly to the main rotor. As a result, the main rotor and tail rotor change speed at the same rate. This means that changes in engine torque are roughly compensated for by changes in the thrust of the tail rotor. As long as throttle changes are made slowly and smoothly, your Lite Machines helicopter will tend to climb and descend without much tail swing.

The main rotor and tail rotor, however, cannot change speed instantaneously. If you suddenly increase or decrease throttle, the change in engine torque will cause the tail to swing. Electronic gyro stabilizers such as piezo gyros sense rotational motion of the helicopter body and control the tail rotor servo to slow down or stop the rotation. Gyro stabilizers reduce tail swing considerably, but not completely.

Piezo gyros (which use a piezo-electric crystal) are sensitive to vibration and temperature changes. A vibrating gyro will send continuous small commands to the tail rotor servo and eventually wear out the servo. To reduce the likelihood of damage to the gyro and tail rotor servo, isolate the gyro from vibration with foam mounting tape or other soft insulation.

In winter, if you store your helicopter in a warm car, and fly in cold air, your piezo gyro may malfunction as it changes temperature causing your helicopter to lose control. Always allow your gyro to come to temperature before flying.

Most all electronic gyros have a "gain" control to adjust the amount of gyro stabilization fed to the tail rotor servo. One way to find the best gain is to start at 50% of full gain and fly your helicopter. If the nose tends to wander or swing in unwanted directions, turn the gain up and fly again. If the tail tends to wave back and forth like a fish swimming, turn the gain down.

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### Hint:

Gyro stabilizers sense only rotational motion. It does not matter where on a helicopter a gyro is mounted as long as it is orientated correctly and does not vibrate excessively. Contrary to common wisdom, mounting the gyro near the main rotor shaft is unnecessary.

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## Adjusting the Arlton Gyro Stabilizer

The dual-gain mechanical *Arlton Gyro* stabilizer on the *Model 110* helicopter greatly reduces tail swing caused by wind gusts or changes in engine speed. If the tail on your *Model 110* helicopter swings excessively with throttle changes, check that all parts of the gyro, tail rotor blades and spider slider linkages are oiled and move very smoothly. Any friction or binding will reduce gyro effectiveness. Also, make sure that your gyro is set to maximum gain (use upper pin location on spider slider/gyro spindle).

Excessive tail swing may also mean that your main rotor and tail rotor are rotating too slowly. Even though the *Arlton Gyro* stabilizer is quite sensitive, at low speeds the tail rotor cannot produce enough thrust to keep the tail from swinging. Generally, adding weight to your *Model 110* will increase main rotor speed and tail rotor effectiveness. In addition, adding weight (like small metal collars) to your gyro paddles can increase gyro effectiveness at low speeds.

The counterweight bolts on the *Model 110* tail rotor blades balance the blades in flight, and influence the operation of the *Arlton Gyro* stabilizer. If the gyro is more effective in one turn direction than in the other, or if the gyro paddles are tilted during hover, the tail rotor blades may not be properly counter-balanced. Replace the 4-40 x 1/4" bolts with 4-40 x 3/8" bolts or 4-40 x 1/8" setscrews until the gyro rotor spins in a vertical plane when viewed from behind.

For more information on helicopter stability, refer to the *Stability, Control Power and Climb Performance* section of this Operator's Guide.

## Tail Swing and Revo Mix

Radio transmitters designed especially for model helicopters usually have a function called "revo-mix" which electronically mixes the throttle control with the tail rotor control. Revo-mix automatically adjusts tail rotor blade pitch each time the throttle setting is changed. Radio transmitters designed for model airplanes do not have this function.

An easy way to simulate revo-mix on an airplane radio is to manually move the throttle (left) stick up and to the left or down and to the right when making rapid throttle changes. Each day before you go flying, look at the throttle stick and repeat to yourself "up and to the left", "down and to the right", "up and to the left", "down and to the right" and you will be able to climb and descend without significant tail swing.





# ***Zen and the Art of Helicopter Maintenance***

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Model helicopters, like their full-size counterparts, spend most of their time shaking themselves apart. The following sections provide a maintenance schedule and basic repair techniques for your Lite Machines helicopters.

## **General Maintenance**

Periodically check all parts of your helicopter for breakage, fatigue cracks, loose screws and normal wear before flying each day and when cleaning up at home. After the first few flights check all nuts and bolts, especially those holding the engine or motor to the crutch. The plywood compresses slightly after assembly and the engine bolts may loosen. Helicopters can also be rough on radio equipment, so check the servos occasionally for proper operation.

Keep your helicopter as clean as reasonably possible, and keep the radio compartment and mechanics free of oil and debris. Oil collects dust and dirt that can cause problems in servo connections and the switch harness. Keep the rotor blades clean of sand and dirt for best performance.

Other than incorrect assembly, most ongoing problems with helicopters are directly traceable to poor maintenance. Not only does this lead to unnecessary frustration, but maintenance failures constitute a serious safety hazard. Periodically review the following maintenance items and suggested maintenance intervals as part of your preventative maintenance program.

## **Engine Maintenance**

- Check all mounting bolts (first after 15 minutes run time, then every 20 flights)
- Check heat sink tightness (every 5 flights, do not hold the rotor head when tightening the heat sink, you may bend the main shaft.)
- Oil the clutch bell bushing (one drop of oil on shaft every 5 flights)
- Check clutch bell pinion for wear (every 30 flights)
- Visually inspect for loose engine backplate (every 50 flights)
- Periodically back flush engine fuel filter (every 50 flights)
- Keep engine free of grit and debris
- Keep heat sink fins clean and unobstructed
- Keep carburetor screen clean and unobstructed

## Brushed Motor Maintenance

- Clean commutator with LiteBrite pad (every 6 to 10 flights)
- Check length of brushes, replace if less than 3/16" (5mm) long (every 10 flights)
- Check color of brushes, replace if blue or black (every 10 flights)
- Oil motor shaft bushings with Lite Lube oil (every 20 flights)
- Check for commutator wear, and replace armature if necessary (every 20 flights)
- Check for damaged connectors and broken power cables (every 30 flights)
- Check pinion gear for wear and replace if necessary (every 50 flights)

## Radio Maintenance

### Transmitter

- Watch power meter when flying (NiCad batteries lose capacity with age, and will gradually lose charge if unused for several days)
- Wipe clean occasionally using soft paper towel and glass cleaner (when necessary)
- Observe battery charging instructions (do not overcharge)
- Do not expose to extreme temperatures

### Airborne System

- Range check before flying (every flying day)
- Check for loose/missing servo mounting screws (every 30 flights)
- Check servo travel (every 30 flights, servos should move smoothly)
- Check servo speed (every 30 flights, servos should move quickly to maximum throw - sluggish response may indicate a low battery, binding linkages or bad amplifier)
- Check wiring for cracks or chafing of the insulation (every 30 flights, especially where rubbing on structure)
- Check plug connections for loosening, and oil or dirt contamination (every 30 flights)
- Keep all components free of oil
- Observe battery charging instructions (do not overcharge)

## Tail Rotor and *Arlton Gyro* Maintenance

- Check tightness of all bolts, setscrews and pins (every 10 flights)
- Oil *Arlton Gyro* stabilizer spindle (every 10 to 15 flights)
- Oil gyro drive linkage (every 20 flights)
- Oil spider and spider slider (every 20 flights)
- Oil tail rotor push/pull rod (every 20 flights)
- Check pitch of gyro paddles (every 30 flights)
- Check gearbox for damage/cracks (every 30 flights)
- Check front and rear bevel gear mesh (every 30 flights)

## Main Rotor Maintenance

- Check tightness of all bolts, setscrews and pins (every 10 flights)
- Check the main rotor hub and blades for cracks, chipped ends and any other damage.

### Warning!

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**DO NOT FLY DAMAGED BLADES. ALWAYS REPLACE BLADES IN SETS.**

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- Check swashplate for wear, adjust if necessary (every 50 flights)
- Check all linkages for wear, binds (every 50 flights, replace ball links if slop develops)
- Check ball bearings (every 100 flights, add oil if they move smoothly, replace bearings that feel “gritty” or drag when rotated)
- Check main rotor hub, replace if bolt hole is enlarged or cracked (every 100 flights)

### Warning!

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**DO NOT USE SOLVENTS (SUCH AS ACETONE) TO CLEAN MAIN ROTOR BLADES! BLADES CLEANED WITH SOLVENTS CAN FAIL WITHOUT WARNING WHEN ROTATING AT HIGH SPEED AND CAUSE SERIOUS INJURIES.** Use only glass cleaners that are safe for plastic eye-glass lenses.

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### Warning!

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**DO NOT ATTEMPT TO REPAIR ROTOR BLADES. REPAIRED BLADES CAN FAIL WITHOUT WARNING WHEN ROTATING AT HIGH SPEED AND CAUSE SERIOUS INJURIES.**

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## Power Train Maintenance

- Check all bolts and setscrews on bearing collars and gears (every 10 to 20 flights)
- Oil main spur and tail rotor crown gear teeth (every 10 to 20 flights)
- Check all gear meshes (every 30 flights)
- Check for wear on gear teeth (every 30 flights)

## Field Equipment Maintenance

- Make sure 12 volt battery for electric starter is fully charged (every flying day)
- Check glow-plug clip wires for breaks or other signs of wear (every 30 flights)
- Clean oil off field equipment (every flying day, oil attracts dirt and is eventually transferred to everything in your flight box)

## Making Repairs with CA and Glass Fiber

The following procedure describes how to make an instant fiberglass patch on a broken part like a wood crutch using CA glue and fiberglass tape.

### Warning!

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**NEVER TRY TO REPAIR THE FLEXIBLE PLASTIC PARTS OR ROTOR BLADES OF YOUR HELICOPTER!** No type of glue (including CA glue) will stick to the plastic, and **THE REPAIRED PART WILL FAIL IN OPERATION AND POSE A SERIOUS DANGER!**

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1. Assemble the necessary supplies: thick CA glue, CA accelerator, heavy fiberglass cloth, coarse sandpaper, a scissors and a small plastic bag (like the parts bags in your helicopter kit).
2. Clean the broken part with window cleaner to remove any oil. Sand an area ½” (13mm) around the break with coarse sandpaper or a grinder to scratch the surface and remove any paint.
3. Cut a piece of heavy fiberglass cloth to fit the patch area.

### Hint:

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Fiberglass cloth does not easily bend around sharp edges. If you are repairing the plywood crutch on your helicopter, apply a separate patch to both sides of the plywood rather than trying to bend a single patch around an edge.

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4. Hold the break tightly closed and apply thick CA glue to the surrounding sanded area.
5. Lay the fiberglass cloth patch over the CA glue, and fill the weave in the cloth with more CA glue.
6. Place the plastic bag over your thumb and spray CA accelerator on the outside of the plastic bag. Press the plastic bag down onto the fiberglass patch and the CA glue will immediately harden.
7. Remove the plastic bag and you will have a smooth fiberglass patch. Trim the rough edges of the patch with a hobby knife or grinder.

### Warning!

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**WEAR A FILTER MASK AND DO NOT INHALE FIBERGLASS DUST!** The sharp glass fibers in the dust can settle in your lungs and cause long term health problems.

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## Making Repairs with CA and Baking Soda

Common baking soda (sodium bicarbonate) is a remarkably good filler material for thin CA glue. Baking soda not only fills small gaps, but also accelerates the hardening of CA glue (like liquid CA accelerator).

To make a rapid repair with baking soda, simply clean and abrade the surface, cover or fill the area with baking soda to a depth of about 1/16" (1mm) and apply several drops of thin CA. The CA will soak into the baking soda and harden almost instantly. Fill deep holes in 1/16" (1mm) layers to insure that CA soaks through all of the baking soda.

Note that baking soda repairs are easy to shape with a hobby knife or sand paper, but are not as strong as fiberglass cloth. For high strength repairs, use fiberglass. For moderate strength repairs and to fill gaps, use baking soda.

## Fixing a Bent Tail Boom

Tail booms are frequently dented by the main rotor blades during crashes or hard landings. Small dents will not affect the flight qualities of your Lite Machines helicopter. A bent boom can usually be straightened by hand several times before being replaced. Small dents can be removed by pushing a 3/8" (10mm) wooden dowel rod into the boom to smooth out the dents. Generally, replace a tail boom at the first signs of cracking, or when the boom becomes so ugly you cannot stand it.

## Straightening a Bent Main Shaft

Main rotor shafts are bent occasionally during crashes. The bend will almost always occur where the shaft is supported by the upper ball bearing.

To straighten a main rotor shaft, first disconnect the swashplate control linkages and remove the main rotor head from the shaft. Attach a pointer (made from a clothespin and paper clip wire) to the top edge of the crutch and set the pointer next to the top end of the main shaft. Rotate the shaft until you can see the direction in which the main rotor shaft is bent. Lightly press on the top end of the main shaft with your thumb in the opposite direction of the bend, then check the shaft for straightness again.



# How Helicopters Work

By Paul Arlton

This section provides a brief technical explanation of certain aspects of helicopter flight control systems, and is included in this Operator's Guide for your interest only. It is not necessary to read this section in order to build or fly your Lite Machines helicopter.

## Introduction

With all of their spinning gizmos and mechanical linkages, model helicopters are intrinsically interesting. Unfortunately, they can also be very expensive and complicated, and traditional model helicopters are not well suited for the average modeler. They usually require considerable patience and understanding (mostly from the other members of your family), and a credit card with a high limit.

Lite Machines helicopters are meant to be different from traditional model helicopters, and their designs reflect the personalities of the people who were involved in their development: Dave Arlton, Paul Klusman and me, Paul Arlton.

As much as I enjoy helicopters, I don't have the patience necessary to be successful with them. Even with airplanes, I rarely allocate adequate time for my projects, and end up immensely frustrated when things don't work. So I concentrate on projects that are simple, inexpensive and less likely to end up as a psychological disaster. I am perfectly content with a simple two-channel Cox .049 powered F6F Hellcat that I built from scratch in a weekend from Styrofoam and Econocote for about \$10.

My brother, Dave, is just the opposite. He revels in the complex and esoteric. In 1987, with dreams of spinning rotors and autorotations impairing his ability to reason objectively, he purchased a Shlüter Champion helicopter for about \$1,600 (that's in 1987 dollars). At the flying field he would wander aimlessly for 30 minutes, building enough courage to attempt his first flights of the day. I never had that problem with my F6F.

One day in 1988, our friend Paul Klusman brought over a rubber-band powered model helicopter he had designed. As I watched it fly, I thought it must be possible to build something similar for radio control. Later, in 1990, after two years of experimentation and development work in the basement, we had a flying model helicopter powered by a Cox .049, and sought a company to manufacture and market it. When Dave and I could not find a suitable company, we decided to build one ourselves. With the help of our parents, we incorporated Lite Machines in the Purdue University Research Park in 1991.

As we developed the prototypes that would eventually become the *Model 100*, we learned a lot more about model helicopters than we really wanted to know. Because we started with little formal education on the subject, however, we often argued about

details without completely understanding the big picture. It would have been handy to start with a basic understanding of helicopters so that we could have discussed some of the problems more intelligently.

The following sections provide a brief introduction to helicopter flight dynamics for those who are just starting and want to know a little more.

## **Background and History**

Helicopters are flying machines with the ability to hover and fly forwards, backwards, and sideways. This agility stems from the multiple capabilities of the main rotor system. Since the invention of helicopters in the early 1900's, considerable effort has been expended advancing helicopter technology, with a substantial percentage of that effort concentrated on the main rotor system.

While the technology of full-size helicopters progressed for decades, model helicopters remained impractical for lack of suitable engines, radio control equipment, and construction materials. As the state-of-the-art in full size helicopters advanced in the 1950's and 1960's, many novel model helicopter designs were developed, but none proved practical. Model helicopter designers often copied the designs of full-size helicopters without understanding the basic differences between full-size and model aircraft. As a result, scaled-down model helicopters were typically unstable, uncontrollable and underpowered.

In the 1970's hobbyists (most notably Dieter Shlüter in Germany) developed the first practical model helicopters. Lighter radio control equipment, more powerful engines and systematic engineering all contributed to early successes. Much of model helicopter design, however, is rooted in tradition. Even though helicopter technology has advanced considerably since that time, the designs and design philosophies of that era are still in widespread use.

Because the main rotor system of a helicopter is capable of performing so many flight functions, it is usually very complex mechanically. Model helicopters currently available contain myriad pushrods, mixing arms, bellcranks, ball joints, and expensive ball bearings, and the trend has been toward higher complexity and prices. High complexity and cost keep many model enthusiasts away from helicopters.

## **Standard Helicopter Configuration**

Both model and man-carrying helicopters are commonly designed with a large main rotor which lifts the helicopter into the air. A smaller tail rotor mounted at the end of a tail boom counteracts the torque produced by the main rotor and steers the helicopter. Both main and tail rotors are driven by an engine usually located within the helicopter fuselage (body) near the main rotor shaft. A streamlined fuselage shell

often covers the front half of the helicopter, but does not always extend back to the tail rotor because of the added weight and complexity of attaching the rear shell to the rest of the helicopter.

From a distance, the main rotor of a helicopter looks superficially like a large propeller sitting on top of the fuselage. The main rotor blades act something like a propeller or fan, and move large amounts of air downward creating a force that lifts the helicopter upward.

Helicopter rotors, however, operate in a manner completely different from propellers on an airplane. Unlike propellers, they are designed to move through the air sideways. In order to control a helicopter in horizontal flight the pilot causes the main rotor to tilt slightly in one direction or another. The offset lift force produced by the tilted main rotor causes the helicopter to move in the direction of the tilt.

## Main Rotor Control

To understand how helicopter main rotor systems work, it is easiest to begin with a simplified representation of a rotor system. Fig. 8-1 shows a schematic rotor blade rotating about a shaft. The rotor blade pitch axis runs down the length of the rotor blade. Blade pitch (also called "angle of attack") is considered positive when the leading edge of the rotor blade is rotated upward about the pitch axis. The aerodynamic lifting force produced by a rotor blade is related to blade pitch. Increased (positive) pitch corresponds to increased lift.

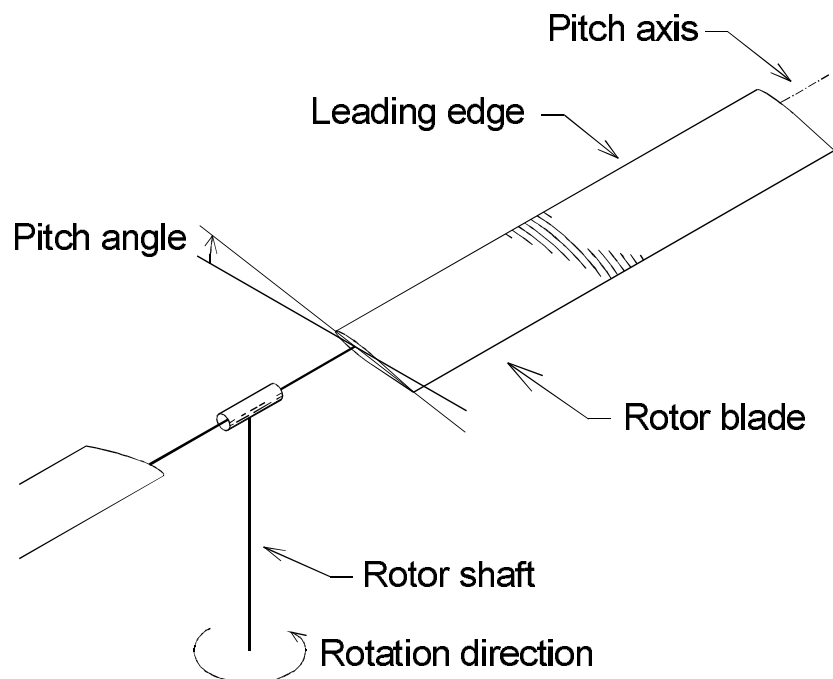
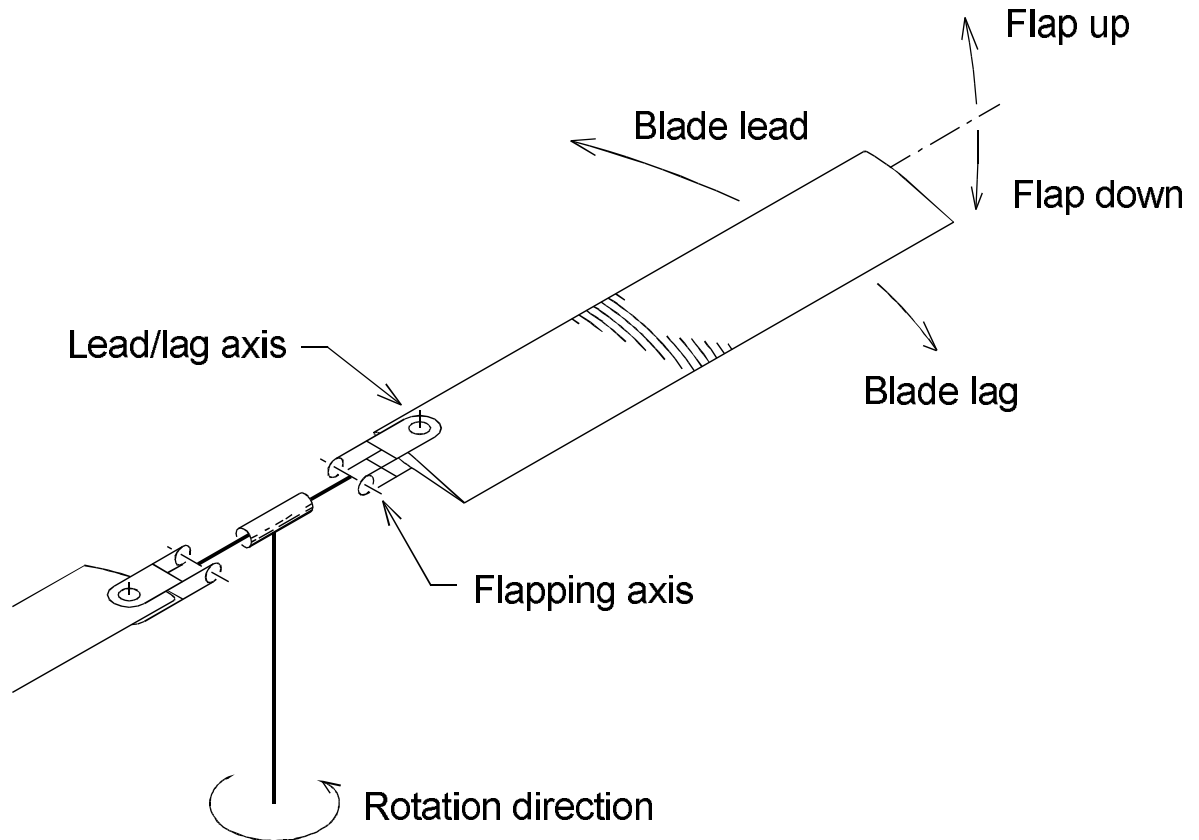


Figure 8-1.



As shown in Fig. 8-2, in addition to a pitch axis, rotor blades are generally hinged near the rotor hub to allow the blade to flap up and down and swing forward and backward. This allows the rotor blades to react to the constantly changing aerodynamic and gyroscopic forces encountered in flight. Without these hinges the rotor blades would likely be unstable, and would need to be built stronger and heavier to withstand in-flight forces

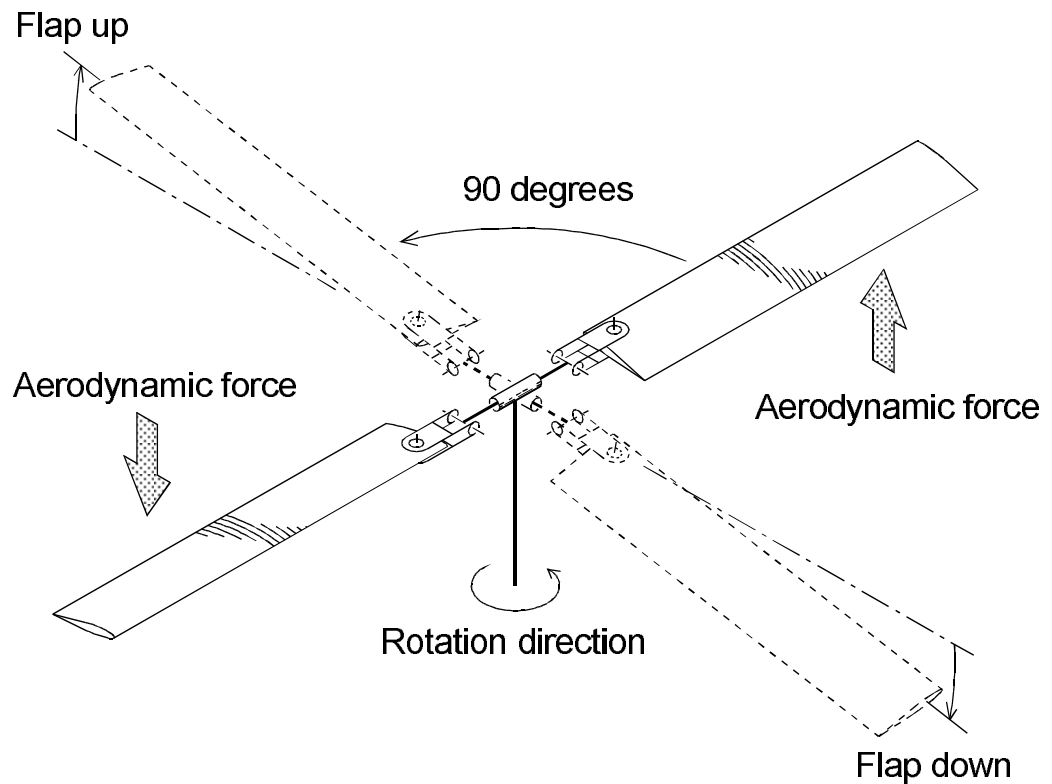


**Figure 8-2.**

Helicopter dynamics are substantially different from airplane dynamics. The rotating main rotor on top of a helicopter acts like an immense gyroscope. As such, the rotor obeys the physical laws of gyroscopes. The basic operating principles of gyroscopes are not obvious, so read the next sentence over a few times because this rule-of-thumb is the key to understanding gyroscopes and helicopters.

***Forces applied to tilt a rotating gyroscope produce motion 90 degrees later in the direction of rotation.***

Why? Because the gyroscope is rotating. If the gyroscope was not rotating, the forces would cause it to tilt where the forces were applied. Since the gyroscope is rotating, it starts to tilt where the forces are applied, but the rotational motion effectively carries the tilting motion along with it. The maximum tilt actually occurs 90 degrees later in the direction of rotation.



**Figure 8-3.**

The rule-of-thumb for gyroscopes is illustrated by Fig. 8-3. If aerodynamic forces are applied to a pair of rapidly rotating rotor blades, the rotor blades, acting under the laws of gyroscopes, will flap 90 degrees later in the direction of rotation. This flapping will be seen by an observer as a tilt of the entire rotor disk (when a rotor rotates at high speed, it is difficult for an observer to discern individual rotor blades, and the rotor appears to be a transparent disk). The aerodynamic forces are created by changing the pitch of the rotor blades, or by air turbulence.

On Lite Machines helicopters, to tilt the rotor disk backward the main rotor blades are pitched to a high angle of attack as they pass around the right side of the fuselage and to a low angle of attack around the left side of the fuselage. The aerodynamic forces produced by this difference in angle of attack cause the blades to flap upward 90 degrees later over the nose and downward over the tail boom thereby tilting the rotor disk backward.

Why 90 degrees, and not some other angle like 62 degrees or 127 degrees? The answer is fairly technical, and involves the concept of mechanical resonance which is a kind of back-and-forth motion such as the motion of a weight swinging on the end of a piece of string. But, forgetting the technicalities, think of it like this: there is no good reason why the point of maximum flapping should be any closer to one of the forces than to the other. If two equal forces are located opposite each other (180 degrees apart), then the maximum flap angle should occur right in the middle at 90 degrees.

Since the main rotor on a helicopter rotates while the fuselage or body of the helicopter does not, some mechanism is needed to transmit control commands from the non-rotating pilot to the rotating main rotor blades. One such mechanism is called a swashplate which is essentially a large ball bearing assembly surrounding the main rotor shaft. In order to tilt the main rotor, the pilot moves linkages attached to the lower half of the swashplate. The upper half of the swashplate is connected through linkages to the rotor blades.

Traditionally, the pilot of a full-size helicopter controls the main rotor by manipulating a joystick called the “cyclic” control located in front of the pilot, and a lever called the “collective” control located to the left of the pilot. Cables, pushrods, and bellcranks connect the cyclic and collective controls through the swashplate to the pitch controls of the main rotor blades.

Main rotor systems of most radio-controlled model helicopters operate in a manner similar to full-size helicopters. The pilot manipulates small control sticks on a hand-held radio transmitter which in turn sends commands to servo actuators located within the flying model. Pushrods and bellcranks connect the servos through the swashplate to the pitch controls of the main rotor blades.

To bank the helicopter to the right or left, or move forward or backward, the rotating rotor blades are pitched upward as they pass around one side of the helicopter and downward around the other. This is called “cyclic” pitching since the rotor blades cycle up and down as the rotor rotates. The difference in lift produced on either side of the helicopter causes the main rotor blades to flap up and down, and the rotor disk appears to tilt. The tilted rotor disk produces a sideways thrust force that then pushes the helicopter in the direction of the tilt.

The large size and high inertia of most helicopter rotors means that they cannot change speed quickly. For this reason, they are usually designed to operate at a nearly constant rotational speed at all times. To control main rotor lift, the main rotor blades are pitched upward or downward in unison. This is called “collective” pitching since all rotor blades move together. The change in pitch, and associated lift force of the rotating rotor blades causes the helicopter to gain or lose altitude.

Some small model helicopters (such as the Lite Machines *Model 110*) rely on variable engine speed instead of collective blade pitch for altitude control since main rotor thrust is proportional to rotor speed as well as blade pitch. The main rotor blades on these models are typically built at a fixed pitch (relative to each other) and are light enough to react quickly to changes in engine speed. The primary advantage of fixed-pitch rotors on models is reduced mechanical complexity and cost.

## Main Rotor Stability

Flight stability is often a problem for small helicopters. To improve stability, weighted stabilizer bars (flybars) are usually incorporated into model helicopters, but are uncommon on modern full-size helicopters. First patented by Stanley Hiller Jr. in 1953 and refined for use on models by Dieter Shlüter in 1970, these flybars are tipped with aerodynamic paddles (Hiller paddles), and are connected through linkages to the swashplate and main rotor blades.

Because the pilot's controls are attached to the flybar, and not directly to the main rotor blades, Hiller control systems naturally exhibit a slight control delay. A hybrid stabilization system referred to as the Bell/Hiller system incorporates additional linkages to mix direct rotor blade control with flybar stabilization. The Bell/Hiller system responds quickly because pilot control commands are transmitted directly to the main rotor blades, while the system is stabilized by a Hiller-type flybar and paddles.

A major drawback of flybars and paddles is increased aerodynamic drag. The circular cross-section flybar wire supporting Hiller paddles can produce more drag than the paddles. Moreover, since Hiller paddles are typically configured to operate at a zero angle of attack relative to the rotor head, and since air passing through the rotor is almost always flowing downward, Hiller paddles can actually operate at a negative angle of attack with respect to the incoming airflow. In this way, Hiller paddles actually contribute negative lift.

The unusual *Artton Subrotor* stabilizer blades on Lite Machines helicopters serve a triple purpose. As part of the main rotor control system, they amplify pilot control commands to the main rotor blades. As part of the stability system, they act to keep the main rotor spinning in a constant plane in space. As rotor blades, they can produce lift that reduces or eliminates the reversed airflow commonly found near the rotor hub.

## Retreating-Blade Stall

Retreating-blade stall (also referred to as "asymmetric lift") affects helicopter rotors that are moving forward (translating). As a Lite Machines helicopter moves forward, the blade swinging forward over the right side of the helicopter (the advancing blade) experiences a higher air speed than the blade swinging backward over the left side of the helicopter (the retreating blade). At high airspeeds the advancing blade generates high lift, while the inner portions of the retreating blade actually move backward relative to the oncoming wind, and much of the retreating blade is stalled. The airflow around the stalled retreating blade is very turbulent and the blade does not generate much useful lift.

Following the rule-of-thumb for gyroscopes, the high lift generated by the advancing blade, and the low lift produced by the retreating blade will cause the main rotor disk to tilt backward away from the oncoming wind. In order to keep a helicopter moving forward at high speed, the pilot has to maintain forward pressure on the transmitter fore-aft cyclic control stick to reduce asymmetric lift and tilt the rotor disk forward.

Retreating blade stall can also be induced by changes in rotor speed. Since Lite Machines helicopters have a fixed-pitch (variable-speed) main rotor, the speed of the rotor must change to control altitude. When descending from altitude the speed of the main rotor is reduced substantially, but forward flight speed does not change. Without pilot intervention, the Lite Machines helicopters will pitch up and fly backwards due to retreating blade stall. It should be noted that helicopters with

collective-pitch (constant-speed) main rotor systems do not normally experience retreating blade stall during descents, and do not require as much forward stick pressure to maintain forward speed.

## Anti-Torque Systems

The torque (reaction force) created by rotating the main rotor of a helicopter in one direction tends to cause the body to turn in the opposite direction. When trimmed for steady hovering flight, the tail rotor at the end of the tail boom creates enough thrust force to balance the torque produced by the main rotor so that the helicopter maintains a constant heading. Decreasing or increasing the thrust force of the tail rotor causes the helicopter to turn in one direction or the other.

The pilot of a full-size helicopter controls the tail rotor by manipulating foot pedals located within the cockpit. The pilot of a model helicopter manipulates control sticks on a radio transmitter which in turn sends commands to servo actuators located within the flying model. Cables, pushrods, and bellcranks connect the pedals or the servos to the pitch controls of the tail rotor blades. The pilot adjusts the pitch and associated thrust force of the rotating tail rotor blades to turn the helicopter.

Although a number of modern anti-torque systems (such as blown tail booms and shrouded fans) have been developed, tail rotors have not changed materially for over 25 years. For reasons of structure and simplicity, and to minimize actuation forces, tail rotor blades traditionally employ symmetrical cross sections such as a NACA 0012 airfoil, and simple constant-chord blade shapes. While easy to build, these rotors do not utilize power very efficiently. Since helicopters have relatively low payload capacities, even small increases in rotor performance can result in large percent changes in payload capacity.

Cambered (curved) airfoils can substantially increase the lifting potential of a rotor blade. Cambered airfoils, however, have a drawback: the curvature of the airfoil causes the airfoil to pitch downward toward negative angles of attack. This pitching tendency can cause the rotor blade to twist and exert high loads on the blade pitch-control linkages (and consequently to the pilot's legs in full-size helicopters, or to the servos in model helicopters).

The unique swept tail rotor blades on Lite Machines helicopters balance the aerodynamic twisting forces of high lift cambered airfoils with other forces. They operate something like canards (little forward wings) on an airplane by balancing the negative twisting force of cambered airfoils with a positive lift force located in front of the blade pitching axis. Small counterweights at the blade root also help to balance the aerodynamic forces. As a result, tail rotor power requirements are lower, and control linkage forces are reduced by as much as 80%.

## Gyro Stabilizers

In general, maintaining a constant heading in hover or low speed flight can be a difficult business for a helicopter pilot. To counterbalance the constantly changing forces on the helicopter fuselage produced by changes in engine torque and atmospheric conditions such as wind gusts, the pilot must continually manipulate the tail rotor controls. This is especially true for models because of their small size and low mass, and the resulting tendency to react rapidly to disturbances.

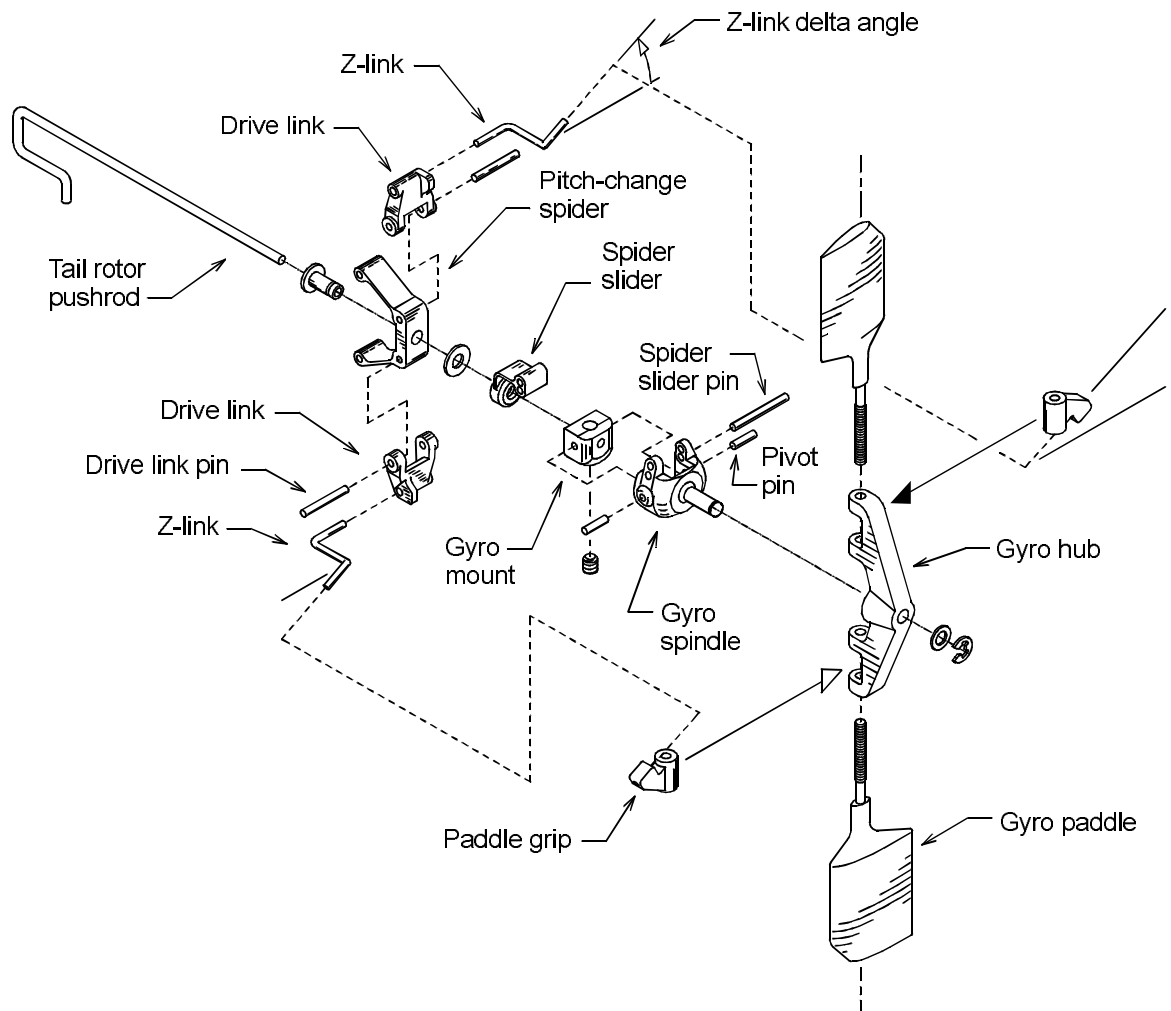
To solve this problem, practically all modern model helicopters are equipped with some sort of auxiliary stabilization system. A gyroscopic stabilizer, or “gyro”, is a device on a helicopter that senses turning motion, and then automatically controls the tail rotor servo and tail rotor to slow down or stop the turn. Basically, a gyro keeps the tail of a model helicopter from swinging so that the pilot can concentrate on other things.

Piezo gyros contain a piezo-electric crystal and an electronic circuit that is sensitive to rotational motion. Piezo gyros are also sensitive to vibration and temperature changes. Since piezo gyros are connected to and constantly control the tail rotor servo, it tends to wear out more quickly than servos attached to other flight controls.

The *Arlton Gyro* stabilizer shown in Fig. 8-4 is a simple mechanical mechanism that attaches to the tail rotor of a helicopter and performs the same function as an electronic gyro. It operates under the same physical laws governing electro-mechanical gyros (see the rule-of-thumb for gyroscopes under the *Main Rotor Control* heading in this chapter), but it is driven and amplified mechanically rather than electronically. It weighs only about ½ ounce (14 gm) and consumes no battery power. Since the *Arlton Gyro* stabilizer controls the tail rotor blades directly, it does not affect the workload of the tail rotor servo.

The aerodynamic paddles and gyro hub on the *Arlton Gyro* stabilizer are supported for rotation by a gyro spindle (see Fig. 8-4) which is free to tilt about two small, steel pivot pins. The pins are connected to a gyro mount which is secured to the end of the tail rotor pushrod on the *Model 110* helicopter. The pushrod extends through the hollow tail rotor shaft (see Fig. 8-5).

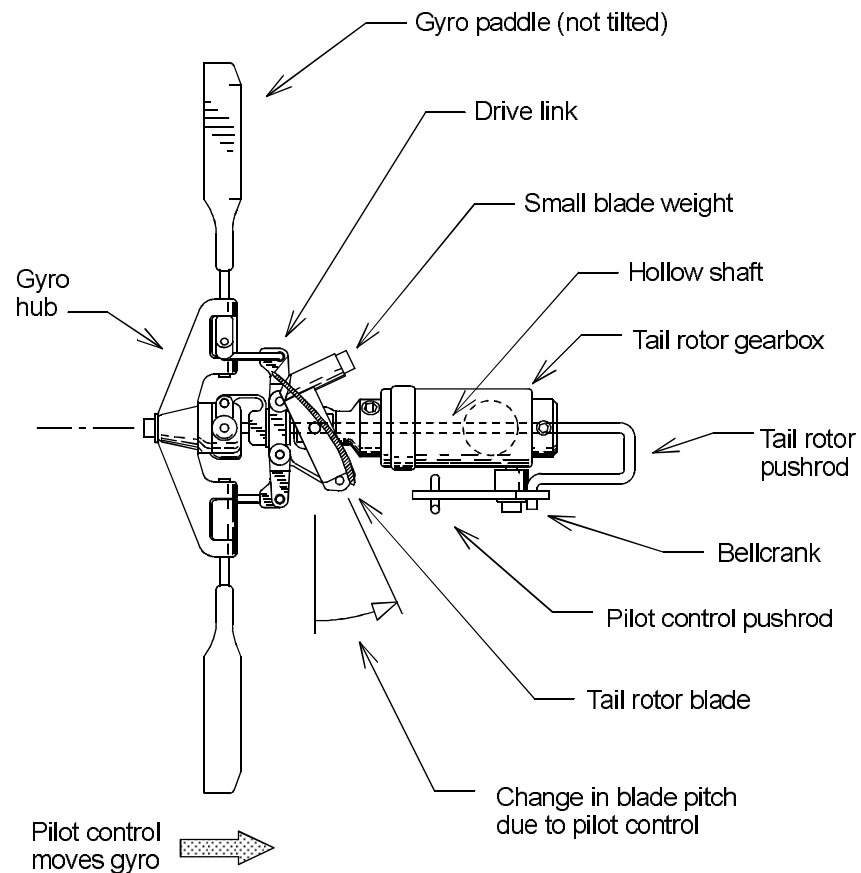
When the body of the helicopter turns, the pivot pins turn with the body and apply forces to the gyro spindle to tilt the paddles about a vertical axis in the direction of the turn. Following the rule-of-thumb of gyroscopes, the paddles actually tilt 90 degrees later about a horizontal axis. As they tilt, they displace linkages (including the spider slider and the pitch-change spider) which change the pitch of the tail rotor blades. This change in blade pitch modifies the thrust produced by the tail rotor, and slows or stops the turning motion of the helicopter.



**Figure 8-4.**

Left to themselves, the gyro paddles will remain tilted unless the helicopter starts turning in the opposite direction. But the small Z-links that connect the paddles to the tail rotor are angled slightly at one end (see Fig.8-4) so that the pitch of the paddles changes as the paddles tilt. This change in paddle pitch generates aerodynamic restoring forces on the paddles that push them back to their initial, untilted orientation (helicopter buffs will understand that this is similar in concept to delta hinges on a main rotor). So, essentially, turning motion of the helicopter causes the paddles to tilt, and the tilted paddles then push themselves upright.

It is interesting to note that the gyro mount may be oriented on the tail rotor pushrod so that the pivot pins are not horizontal. In this configuration, the gyro will sense rolling motions as well as turning motions. In this way the gyro can be set to coordinate turns by modifying the thrust of the tail rotor when the helicopter rolls. This is something like adding rudder when turning an airplane with ailerons.



**Figure 8-5.**

The *Arlton Gyro* stabilizer works automatically without any input from the pilot, but at some point the pilot may wish to trim the tail rotor or turn the helicopter without interference from the gyro. To turn the helicopter, the pilot controls the tail rotor servo which moves the tail rotor pushrod back-and-forth. As shown in Fig. 8-5, the tail rotor pushrod passes from the right side of the gearbox completely through the hollow tail rotor shaft and extends out the left side. Since the gyro is mounted to the end of the pushrod, the entire gyro assembly moves back-and-forth along with it.

The rule-of-thumb for gyroscopes states that a gyro will react to tilting forces, but the rule says nothing about moving the whole gyro back-and-forth. In fact, linear (non-tilting) motion of the gyro has no effect on the gyro whatsoever. This means that the gyro will not tilt, and will not change the pitch of the tail rotor blades when the pilot moves the tail rotor controls. The gyro will operate only when the body of the helicopter turns.

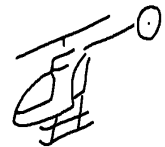
When the helicopter starts to turn under pilot control, the gyro will tilt about 20 degrees before reaching an end limit. Once there, it will no longer be able to modify the pitch of the tail rotor blades, and so it will stop opposing the turn. This means that after the helicopter turns a certain amount, the pilot will have amplified tail rotor control authority (something like having dual-rates on the transmitter).



The aerodynamic and mechanical characteristics of the tail rotor have a substantial impact upon the operation of the *Arlton Gyro* stabilizer. The actuating power of a purely mechanical gyro stabilizer is determined by the rotational speed, size and mass of the gyro paddles and gyro hub. Given a particular tail rotor rotational speed, high actuation forces require large diameter and/or heavy gyro paddles. Tail rotor blade actuation forces, therefore, must be kept low to minimize the size and weight of the gyro.

Undercambered airfoils can greatly increase the thrust of the tail rotor, but the pitching forces generated by undercambered airfoils can also exert high loads on the tail rotor blade pitch-control linkages, and consequently on the gyro. The tail rotor blades on the *Model 110* helicopter are aerodynamically and centrifugally balanced to operate in conjunction with the *Arlton Gyro* stabilizer. Small weights are provided at the root of each blade for fine tuning the pitching forces. If the blades are not completely pitch-balanced, the gyro will tilt slightly even when the helicopter is not turning. In this case, the small weights should be replaced with lighter or heavier weights until the gyro no longer tilts noticeably.

The *Arlton Gyro* stabilizer on the *Model 110* is only one member of a family of simple mechanical gyros. Over 20 variations have been developed to suit various helicopter configurations. With certain modifications to the structure of the helicopter, the gyro may be located on either side of the tail rotor, on the gearbox opposite the tail rotor, or elsewhere on the helicopter. Since the gyro can be adapted to produce a thrust force like that produced by the tail rotor, some configurations have multiple rotors, while others omit the tail rotor entirely and have only a single gyro-rotor. All of these variations, along with the other unique features of Lite Machines helicopters, are patented in the United States and countries all over the world.



# Trouble-Shooting Glow Engines

This section identifies a variety of problems that you may encounter when starting and operating the Norvel engines on a Lite Machines helicopter. Possible causes and suggested actions are also provided.

<b>Engine will not pop:</b>	
Glow plug bad	<i>Remove glow plug and test. Try different glow plug.</i>
Glow plug clip bad	<i>Test clip on another glow plug.</i>
Glow plug battery bad	<i>Recharge glow plug battery or replace if necessary.</i>
Electric starter draining glow plug battery	<i>Recharge battery, use larger capacity battery, pulse starter at one-second intervals, use smaller starter, or use separate glow plug and starter batteries.</i>
Glow plug voltage low	<i>Check glow plug battery or power panel for proper operation.</i>
Engine not primed (not enough fuel)	<i>Hold finger over carburetor inlet and spin engine to pull fuel into carburetor.</i>
Engine flooded (too much fuel)	<i>Close needle valve and try starting engine to burn-off excess fuel. Open needle valve and try starting engine again.</i>
Bad/old fuel	<i>Buy new fuel, change brands (fuel must contain castor oil).</i>
Heat sink loose	<i>Tighten heat sink (protect your hand with cloth). If necessary, apply a very small amount of thread lock (temporary type) to heat sink threads.</i>
Compression too low	<i>Remove glow plug washers (leave at least one washer in engine).</i>
Needle valve closed	<i>Open needle valve 2 to 2-1/2 turns.</i>
No fuel in tank	<i>Add fuel (and consider a simpler hobby).</i>

<b>Engine pops but will not start:</b>	
Compression too high	<i>Add glow plug washers.</i>
Glow plug bad	<i>Remove glow plug and test. Try different plug.</i>
Fuel mixture too lean	<i>Open needle valve ½ turn.</i>
Glow plug coil touching glow plug body	<i>Pull coil lightly away from plug body with hobby knife (SpiraLite Speed plug only).</i>
Carburetor clogged	<i>Remove needle valve and fuel line. Back-flush needle valve body with fuel. Reassemble needle valve and fuel line.</i>
Bad/old fuel	<i>Buy new fuel, change brands (fuel must contain castor oil).</i>
Electric starter too slow	<i>Try Lite Machines high-speed micro starter. Check charge of starter battery.</i>
Electric starter holding back engine	<i>Remove starter from engine when engine starts popping</i>

<b>Engine pops, fuel sizzles, fuel drips out of carburetor:</b>	
Engine flooded (too much fuel)	<i>Close needle valve and try starting engine to burn-off excess fuel. Open needle valve and try starting engine again. Some fuel dripping from carburetor is normal when fuel tank is full and the oil provides lubrication for the goop clutch.</i>

<b>Engine runs rough (four strokes), sputters and dies:</b>	
Mixture too rich	<i>Close needle valve ½ turn.</i>

<b>Engine runs at high speed for a few seconds then stops:</b>	
Fuel line not filled with fuel	<i>Hold finger over carburetor inlet and spin engine to pull fuel into carburetor.</i>
Needle valve not adjusted correctly	<i>Close needle valve completely then open 2 to 2-1/2 turns.</i>
Carburetor clogged	<i>Remove needle valve and fuel line. Back-flush needle valve body with fuel. Reassemble needle valve and fuel line.</i>

<b>Engine runs at full power for 1-2 minutes then suddenly stops:</b>	
Mixture too lean	<i>Open needle valve 1/8 turn.</i>
Cylinder head leak	<i>Oil bubbles around glow plug indicate a leak under glow plug. Make sure glow plug seat is clean and washers are not bent.</i>
Bad glow plug, glass seal leaking	<i>Replace glow plug (normal tests will not find this problem).</i>
Carburetor clogged	<i>Remove needle valve and fuel line. Back-flush needle valve body with fuel. Reassemble needle valve and fuel line.</i>

<b>Engine not producing high power:</b>	
Fuel mixture too rich or too lean	<i>Adjust needle valve. Make sure to run engine for 20-30 seconds before adjusting needle valve so that engine is hot.</i>
Compression too low	<i>Remove glow plug washers (leave at least one washer in engine).</i>
Compression too high, fuel pre-detonating	<i>Add glow plug washers.</i>
Bad/old fuel	<i>Buy new fuel, change brands (fuel must contain castor oil). Do not use fuel containing rust inhibitors. Do not use dirty fuel containers.</i>
Bad/old glow plug	<i>Replace glow plug (coil becomes coated over time with combustion by-products which prevent good catalytic ignition of the fuel).</i>
Heat sink loose	<i>Tighten heat sink (protect your hand with cloth).</i>
"Varnish" buildup on piston/cylinder (looks light brown)	<i>Remove varnish (a byproduct of over-heated castor oil) with 3M Scotchbright cloth or fine steel wool. Never use sandpaper!</i>
New engine not completely broken-in	<i>Follow manufactures break-in instructions.</i>
Crankcase back plate not tight	<i>Remove engine and back plate, apply thread lock (temporary type) sparingly to back plate threads and reassemble.</i>
Not enough nitromethane in fuel	<i>Use fuel with more nitromethane (15%-35% nitro recommended).</i>

<b>Engine losing power over time:</b>	
Air temperature/humidity changing compression	<i>If air much cooler, add glow plug washer; if much warmer, remove washer.</i>
Dirt particle scratched cylinder wall or crankshaft seal	<i>Replace piston/cylinder or crankcase.</i>
"Varnish" buildup on piston/cylinder (looks light brown)	<i>Remove varnish (a byproduct of over-heated castor oil) with 3M Scotchbright cloth or fine steel wool. Never use sandpaper!</i>
Crankcase back plate not tight	<i>Remove engine and back plate, apply thread lock (temporary type) sparingly to back plate threads and reassemble.</i>
Old engine naturally wearing out	<i>Replace engine.</i>

<b>Engine sound "warbles" (oscillates) at high throttle, overheats:</b>	
Main rotor blade pitch too high, engine overloaded	<i>Change one blade grip to lower blade pitch and re-track rotor blades.</i>
Compression too high, fuel pre-detonating	<i>Add glow plug washer(s).</i>
Bad ball bearing on main rotor or tail rotor	<i>Replace bearing (bad bearing may not be noticeable when turned by hand, or may feel slightly gritty).</i>
Gear mesh too tight/ too loose	<i>Remesh gears. Make sure engine mounting bolts are tight.</i>
Gyro dragging	<i>Relubricate gyro hub and gyro spindle.</i>
Rotor head not balanced (everything shaking)	<i>Rebalance rotor head.</i>
Rotor blades not tracking (everything shaking)	<i>Track rotor blades.</i>
Main shaft bent (everything shaking)	<i>Remove main rotor from main shaft. Attach paper clip wire or other pointer to fuselage keel and rotate shaft by pointer to determine direction of bend. Press firmly on top of shaft with thumb in direction opposite of bend. Repeat procedure until shaft is straight. Reassemble main rotor.</i>

<b>Engine sound oscillates at all throttle settings:</b>	
Clutch shaft loose, clutch shoes slipping against prop plate	<i>Tighten clutch shaft in end of engine crankshaft.</i>

<b>Engine suddenly stops at low throttle or while descending from altitude:</b>	
Compression too high, fuel pre-detonating	<i>Add glow plug washers.</i>
Bad glow plug, glass seal leaking	<i>Replace glow plug (normal tests will not find this problem).</i>
Carburetor clogged	<i>Remove needle valve and fuel line. Back-flush needle valve body with fuel. Reassemble needle valve and fuel line.</i>

<b>Engine runs well for 20 to 30 seconds then sags:</b>	
Fuel mixture too lean, engine slowly overheating	<i>Open needle valve slightly.</i>
Compression too high, fuel pre-detonating	<i>Add glow plug washers.</i>
Heat sink loose	<i>Tighten heat sink (protect your hand with cloth). If necessary, apply a very small amount of thread lock (temporary type) to heat sink threads.</i>
New engine not completely broken-in	<i>Follow manufactures break-in instructions.</i>
Improper fuel, engine seizing	<i>Use fuel containing castor oil or castor/synthetic oil blend. Some pure synthetic oils break down at high temperatures and can damage small engines.</i>

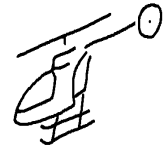
<b>Engine runs inconsistently:</b>	
Something is leaking	<i>Check needle valve, crankcase back plate and carburetor for leaks.</i>
Hole in fuel tubing	<i>Replace fuel tubing.</i>

<b>Engine running very fast, but <i>Model 110</i> will not fly:</b>	
Rotor blade pitch too low	<i>Change blade grips to increase main rotor blade pitch.</i>
Local altitude/temperature/humidity too high	<i>Wait for air temperature/humidity to drop. If possible, fly at a lower elevation.</i>

<b>Engine will not turn, electric starter slips on starter cone:</b>	
Excess fuel in cylinder causing hydraulic lock above piston	<i>Do not force engine to turn with electric starter! Remove heat sink and glow plug, and spin engine for one second to clear out excess fuel. Replace plug and heat sink.</i>
Starter cone covered with oil	<i>Clean engine starter cone and rubber insert on electric-starter motor with a paper towel.</i>

<b>Engine runs for many flights, but then runs poorly or does not start:</b>	
Carburetor clogged	<i>Remove needle valve and fuel line. Back-flush needle valve body with fuel. Reassemble needle valve and fuel line.</i>
Bad fuel fouling glow plug	<i>Buy new brand of fuel, change glow plug.</i>

<b>Nothing will work, situation is hopeless:</b>	
Gremlins in system	<i>Call Lite Machines</i>



# Trouble-Shooting Brushed Motors

This section identifies a variety of problems that you may encounter when operating an *Electro-Fusion* brushed motor your *Corona electric* helicopter. Possible causes and suggested actions are also provided.

<b>Motor losing power/flight times going down</b>	
Commutator oxidized/dirty	<i>Clean commutator with LiteBrite pad</i>
Commutator worn	<i>Replace armature and brushes</i>
Brushes worn/burned	<i>Replace brushes</i>
Power connections loose/worn	<i>Change connectors on battery, speed controller and/or motor</i>
Battery not charged	<i>Recharge battery</i>
Bad cell(s) in battery pack	<i>Change battery pack</i>
Motor timing wrong	<i>Set motor timing to 20 degrees</i>
Motor over/under loaded	<i>Check blade pitch and helicopter weight</i>
Gears binding	<i>Adjust gear mesh</i>
Ball bearing dragging	<i>Replace main shaft and/or tail rotor bearings</i>
Swashplate dragging	<i>Lubricate swashplate with Lite Lube grease</i>
Filter capacitors installed	<i>Remove filter capacitors</i>

<b>Motor turns off or will not start</b>	
Commutator oxidized/dirty	<i>Clean commutator with LiteBrite pad</i>
Commutator worn	<i>Replace armature and brushes</i>
Brushes worn/burned	<i>Replace brushes</i>
Battery/motor disconnected	<i>Check cables and power connections to battery and motor. Check for broken wires.</i>
Speed control not armed	<i>Perform arming sequence</i>
Radio signal lost	<i>Perform arming sequence</i>
Bad cell(s)/short circuit in battery pack	<i>Change battery pack</i>
Speed controller damaged	<i>Send speed controller to manufacturer for service</i>
Throttle backwards, speed controller not arming	<i>Unplug battery and reverse transmitter throttle channel</i>
Filter capacitors installed	<i>Remove filter capacitors</i>



<b>Tail swings after landing</b>	
Low battery, gyro turning off	<i>Land sooner with more battery power</i>
BEC not supplying adequate voltage to gyro	<i>Use separate receiver battery</i>

<b>Motor turns backwards</b>	
Motor connections backwards	<i>Reverse power cables on motor. <b>DO NOT CHANGE POWER CABLES ON BATTERY</b></i>

