Emergency Procedures

These are general procedures dealing with emergency situations. Every helicopter is different, and the pilot needs to understand the exact emergency method recommended by the helicopter manufacturer in the appropriate POH. These descriptions are meant to deal with emergencies in a generic way and should not be used in a particular model of helicopter.

Hovering Autorotation

This maneuver is used to land from a hover without using the engine. This would normally occur because the engine or tail rotor failed. The name "hovering autorotation" is really a misnomer, because the helicopter actually never enters autorotation. Instead, the inertia of the spinning rotor system is used to produce thrust.

A JPEG and GIF sequence of photographs of a hovering autorotation are available.

Maneuver Description

The rotor system of a typical helicopter stores a fair amount of kinetic energy. This energy can be extracted as thrust by allowing the rotor RPM to decrease, giving up the stored energy. There is only a limited amount of energy available, and this determines the maximum height from which the helicopter can be landed without damage.

Collective and Throttle Controls

To practice a hovering autorotation, the pilot rolls the throttle to the off position while in a hover. The freewheeling unit allows the powerplant RPM to go to idle (or zero) while the rotor coasts. As the rotor RPM starts to decay, less thrust is developed and the helicopter will begin a descent toward the ground. As the ground is approached, the pilot can cushion the landing by increasing collective pitch. This bleeds the RPM down even more rapidly, but provides extra thrust to slow the descent rate of the helicopter. The helicopter will land gently if sufficient energy was available in the rotor system at the time the engine power output stopped.

Normally on entry to the maneuver, the collective pitch is not moved. This uses up considerable rotor energy as the helicopter sits in the hover, starting to descend very slowly. The pilot can achieve a softer landing if he initially lowers some collective. This starts the helicopter down toward the ground faster, and conserves rotor RPM. This is considered an advanced technique and is not normally taught to low time pilots.

Cyclic and Pedal Controls

When the throttle is rolled off, any torque being produced by the engine stops immediately. The pilot must reduce the anti-torque force being produced by the tail rotor, since there is no longer a torque force to counter. He does this by pushing right pedal (in most American helicopters) until the tail rotor is approximately at flat pitch. This will not be full right pedal, since the tail rotor is actually able to go past flat pitch and into "negative" pitch. The exact position of the pedals will depend on how the helicopter is rigged, but the pilot simply judges the amount of pedal by putting it in whatever position prevents any yaw from occuring.

While the helicopter was hovering, the tail rotor was producing thrust which not only prevents the helicopter from spinning due to torque, but also has the useless side effect of trying to push the helicopter sideways. This is called *translating tendancy*. This is opposed by tilting the main rotor to the left, providing equal and opposite thrust. When the tail rotor is placed in flat pitch, the translating tendency goes away, and therefore the lateral main rotor thrust must also go away. The pilot does this by simultaneously moving the cyclic to the right as he pushes the right pedal. The timing of the two must by synchronized. If the pedal is moved quickly, the cyclic must move quickly. If the pedal moves slowly, the cyclic must move slowly.

As the ground is approached and the collective is raised, student pilots will often want to push left pedal, because they are used to pushing left pedal as they increase collective. However in this case there is no torque being generated, so the pedals remain fairly motionless as the collective is raised to cushion the landing.

Common Mistakes

One of the difficult aspects of learning hovering autorotations is that they occur very quickly. The entire maneuver only lasts a 2-3 seconds.

Raising collective during the throttle rolloff

As the pilot rolls off throttle, it is possible to inadvertently raise the collective slightly. This has the unfortunate effect of using up some of the rotor RPM to gain altitude. This has the effect of placing the helicopter even further from the ground with less RPM available, and generally results in a firm or hard landing. The pilot has to be very careful that the collective does not move while the throttle is being rolled off.

Allowing the helicopter to yaw

The pedals must be moved fairly quickly to approximately the correct position if the pilot is going to avoid yawing the helicopter on entry to the maneuver. Errors in either the speed at which the pedals are applied, or the actual position the pedals are moved to will cause the helicopter to yaw. Minor mistakes can be corrected before the helicopter touches down, but a really good hovering autorotation will transition from powered to unpowered flight with no noticible change in aircraft attitude.

Allowing the helicopter to drift

The cyclic is another difficult control during this maneuver. The cyclic is normally moved in very small increments during a hover. In a steady hover, the cyclic will appear to be motionless even while corrections are being made, because the corrections are so small. At the entry to the hovering autorotation, the cyclic has to move a huge amount: an inch or more in some helicopters. The cyclic is so sensitive that it is difficult at first to move it so far, to exactly the correct position, and then revert to very small inputs to maintain level flight.

The result of this is that the helicopter is likely to drift either forward, sideways, or backward during the hovering autorotation. Forward drift is not normally a big problem because the landing gear is designed to allow touchdown with forward speed. Sideways and rearward drift is more of a problem. The landing gear is usually not designed to take very high side loads, and landing while drifting sideways can cause the helicopter roll over, or even if a roll over is avoided the side loads can damange the helicopter structure.

If the helicopter starts to drift, the pilot should make corrections with the cyclic just as in normal flight. Drastic sideways drift that cannot be corrected with cyclic may require that the pedals be used to align the landing gear with the drift. For instance, if the helicopter is drifting right, the right pedal could be pushed to yaw the helicopter nose to the right until it is now aligned with the direction the helicopter is moving.

Collective pull too soon or too fast

If the collective is raised too early or too rapidly, the helicopter may stop the descent for a moment, bleed of rotor RPM, and then descend again (but now with less RPM available to cushion the landing). This sort of mismanagement will often cause firm or hard landings because there may not be enough RPM left to maintain rotor thrust until the landing occurs. The helicopter may literally fall the last few feet, and this will result in a *very* hard landing.

Collective pull too late

Sometimes the pilot will fail to pull collective soon enough. This may simply mean that the landing is not cushioned as much as it could be. A possible problem is if the helicopter has flexible landing gear. If the helicopter lands hard enough to compress the landing gear, and the pilot continues to pull collective pitch, as the rotor thrust builds the landing gear can spring the helicopter back up into the air. The problem is that at this point no rotor RPM is left, and if the helicopter springs up to a 2 foot skid height, it will *fall* 2 feet back to the ground. 2 feet does not sound like a lot, but it's enough to damange many helicopters.

A word about hover autos in turbine aircraft

The first time anyone performs a hover auto in a turbine aircraft, they think *wow* because everything happens in slow motion compared to in a piston helicopter. However, there is something strange going on when the throttle is rolled off. The torque change is very gradual, as shown by the fact that the right pedal has to be moved very slowly. There are two possible reasons that I have come up with for this, but so far these are theories on my part. What I really think is happening here is that when you roll throttle off in a turbine aircraft, the fuel control is going to reduce fuel on a schedule designed to not flame out the engine. Even though the pilot may snap the throttle off, the fuel control is actually reducing fuel to the engine at a very slow rate. Therefore, substantial engine power is being developed during the hovering autorotation. If I am correct, a flameout will cause a rapid power loss, and the hover autorotation will happen at a pace similar to that of a piston powered helicopter. One other possibility is that the turbine itself may store significant rotational energy: it's turning at over 50,000 RPM. Why I don't like this theory as much is that in a free turbine engine, the power turbine is pretty small and light, and even at 50,000 RPM I doubt it can store really significant amounts of energy. If anyone has flamed out a turbine at a hover, or knows for sure why the loss of torque is so gradual, I'd be interested in hearing from you.

In any case, I've noticed a large discrepency in how much inertia I seem to have performing a hovering autorotation in a turbine aircraft, versus how much inertia I seem to have doing full down autorotations from altitude. I think that in this case, the turbine has plenty of time to wind down to idle while in the autorotational glide, and that the pitch pull and landing at the bottom of the auto accurately reflects how much inertia is actually available without the engine producing power.

The obvious danger with this situation is that if pilots practice hovering autorotations in turbine aircraft by rolling off throttle, they may get a false sense of the amount of inertia available to them. This may cause them to hover at altitudes which appear to be safe for a hovering autorotation (because the pilot has practiced hover autos from that altitude) but which may be too high to effect a safe landing if the engine actually flames out.

Tail Rotor Failure at a Hover

There are a couple ways a tail rotor can fail while at a hover. The tail rotor can be stuck at a particular pitch setting, but still be producing thrust, or the tail rotor can stop producing thrust. A slight variation on the second is that if one blade fails to flat pitch, the tail rotor may be producing half the normal thrust.

Stuck Pedals (fixed pitch failures)

A fixed pitch failure of the tail rotor is one kind of failure, but we tend to charactersize it as stuck left, stuck right, or stuck neutral. This is because depending on what pitch setting it is stuck at will determine what kind of a recovery we will do.

Stuck neutral

This is probably the most likely fixed pitch failure to occur. It would happen either because the pitch change mechanism failed while the tail rotor was at flat pitch, or more likely that the pitch change mechanism failed, and air loads drove the tail rotor to flat pitch. In either case, the recovery is the same as if the tail rotor stopped producing thrust; the pilot performs a hovering autorotation.

Stuck right

In this case, the tail rotor and the engine are both producing thrust to the right. The spin will be quite rapid. The pilot should roll off the throttle to get rid of engine torque. This will slow the spin, but not stop it because the tail rotor thrust alone is capable of spinning the helicopter. The next thing the pilot should do is his best hovering autorotation, preferably over a flat piece of hard surface, although he's going to have to take pretty much whatever was under him at the time.

One thing he can try to do is to hold the helicopter off the ground as long as possible with collective. As RPM decays, the tail rotor thrust will decrease and the spin rate should slow, but not stop. The helicopter will contact the ground spinning (but hopefully slowly) and may roll over if the ground is uneven, or the pilot did not hold the skids level. Chances are fair, however, that the helicopter will remain upright on the landing gear.

One thing I was shown by a friend who chopped his entire tailboom off with a wire is that if a pilot is trained properly, he can maintain a helicopter in a level attitude at a very rapid spin. However, most pilots are not given this training which is a shame. Although you can get dizzy from practicing this, it is not dangerous and any pilot can be quickly taught how to keep the skids level even during a very rapid spin.

Stuck Left

(to be supplied)

Autorotation

Autorotations are used to perform power off landings from altitude in the event of an engine failure.

Maneuver Description

An autorotation is used when the engine fails, or when a tail rotor failure requires the pilot to effectively shut down the engine. It is very similar to gliding in an airplane.

The entry

To enter the autorotation, the pilot lowers collective all the way down, simultaneously adding right pedal. Lowering the collective maintains RPM during the entry to autorotation, and keeps the AOA (angle of attack) at a normal value during the glide.

Adding the right pedal is necessary because in autorotation there is no torque. During power-on flight, the pilot was using a lot of left pedal to counter the torque being produced by the engine. Once the helicopter is autorotating, the engine disengages and produces no more torque.

While the collective is being lowered, the nose of the helicopter has a tendancy to pitch down. The pilot needs to use aft cyclic to prevent this. Allowing the nose to pitch down creates two problems: it tends to reduce RPM because it decreases the amount of airflow through the rotor disk, and it tends to increase airspeed, usually far above the range you want to use while autorotating.

Establishing the glide

As the air starts flowing up through the rotor system, the RPM will start to increase, and depending on how the helicopter is rigged, the RPM may get too high. In this case, as RPM gets high the pilot can increase collective pitch to lower RPM.

The pilot should set up a normal autorotational attitude in order to get a normal airspeed. Although helicopters will autorotate at zero airspeed and even at negative airspeed, normally the pilot will want to hold between 60-70 knots of airspeed during the glide.

Selecting a landing area

Hopefully within the first few seconds the pilot will establish autorotation and will have selected a landing area. The approach to the landing should almost *always* be into the wind, so the pilot needs to select a spot which will allow him to maneuver for an upwind approach.

The spot should normally be flat, firm, and fairly level. A spot like this is not always reachable, but is obviously preferred.

One thing I quickly look for is poles which may have wires strung. If I have *any* other place to land, I'll stay away from one which may have wires. The last thing I need to be doing on short final is trying to duck wires!

Once the pilot has selected a landing area, I recommend he visualize a standard traffic pattern imposed on the landing area and aligned with the wind. The pilot should figure out which leg he is currently on, and then fly the pattern so that he arrives on final approach at an altitude and airspeed which will allow him to land in the selected area.

By flying a rectangular traffic pattern, the pilot can find himself on base leg, watching the angle to the landing area. When the angle is right, he simply turns final and will be very close to the desired spot. If the pilot starts to see the angle before he reaches the extended "centerline", he can simply turn final early. By cutting the corner he reduces the distance he has to fly, and makes it to the spot without ending up too low.

If the pilot finds himself slightly high on base, he can simply fly through the extended centerline, and turn a little late onto final. The extra distance uses up some extra altitude, and he still makes it to his spot.

A little overshoot is preferable to a little undershoot because it can be corrected easilly still leaving sufficient energy. An undershoot normally requires going to best glide airspeed and dragging the rotor RPM down to the lowest allowable value. If the pilot is not careful, the result may be reaching the spot with low RPM. This is probably not a problem with a light inertia rotor system, but in a high inertia rotor system the RPM might not be recovered before touchdown.

The Flare

The pilot initiates the flare by using aft cyclic. No collective or pedal input is normally required. The height that the pilot should start to flare at depends on many factors, including the model helicopter, the descent rate, the airspeed, the descent rate, the headwind component, and how rapidly the pilot is going to move the cyclic.

The purpose of the flare is twofold. First, it slows the descent rate of the helicopter, from 1,000 or 2,000 feet per minute to much less, so that a soft touchdown can be made. It also reduces the forward ground speed to just a few knots (we hope!) so that sliding on the landing gear is minimized.

The flare must be timed to not zero the descent rate, because the helicopter would be left hanging in the air bleeding RPM, but rather the flare should be timed to slow the descent rate so that the helicopter is approaching the ground at a managable rate. The descent rate should be decreasing so that it either goes to zero just above the ground, or is low enough that a little collective pitch can bring it to zero.

The Landing

Touchdown is accomplished by (typically) putting the helicopter into a level attitude, and then using the collective to cushion the landing, just as in a hovering autorotation. The pedals are used to align the landing gear with the ground track.

Power Recovery

If the pilot is practicing an autorotation he may decide to recover to a hover, rather than touch down. The procedure is to start raising collective while still in the flare, just as flare effectiveness starts to go away, before any increase in sink rate is experienced. By starting the recovery early, the engine is not trying to play catch-up, and the recovery can be made with the RPM in the green range at all times.

Common Mistakes

Gosh there are a lot! Here are a few:

Failure to Lower Collective all the way down

If the pilot forgets to lower collective and this is a real engine failure, it's a fatal mistake. Lowering collective is the most important part of doing an autorotation. If you remember to do that, you will probably walk away from the landing. Some pilots only put the collective pitch part of the way down. They get to "know" where it belongs. The only problem with this is that the position the collective needs to go to depends on many factors such as pitch link rigging, gross weight, and density altitude. These things can change from day to day. This method also delays recovery of rotor RPM, and there is no good reason to do that.

The best method is to lower collective all the way, and as RPM starts to build back up some collective should be raised to stop the RPM somewhere in the operating range.

Failure to trim with anti-torque pedals

Pilots will either forget to push right pedal, or push too much, or even sometimes push the left pedal! In any case, the aircraft should be autorotated in trim, and the pilot can do this by putting in the correct amount of right pedal when the engine fails.

Allowing the nose to drop

We already discussed it, but I'm repeating this because it's one of the most common errors I see during the entry. Do *not* let the nose drop during the entry. Whatever attitude the helicopter is in, enter the autorotation in that attitude, and then after the autorotation is established the pilot can make any attitude adjustments required for proper airspeed. Allowing the nose to pitch down delays the recovery of RPM (it's like an anti-flare) plus it is not uncommon for pilots to overspeed the rotor by waiting until the airspeed builds to 80 knots or more, and then suddenly trying to fix it by yanking back on cyclic. The result is an almost instantaneous rotor overspeed.

Failure to control Rotor RPM with collective

Most helicopters are rigged so that at normal weights the collective will have to be raised somewhat to keep rotor RPM in the normal operating area. Common mistakes are either to leave the collective full down so long that a rotor overspeed occurs, or to overcontrol the collective, moving it up and down during the entire glide. The proper way to manipulate collective is to lower it full down during the entry to autorotation. Then, as RPM starts to increase toward the normal operating area raise enough collective to stop the RPM from changing. Wait a few seconds until it stabilizes, and make one final adjustment to place the RPM exactly where it is desired. Normally no further manipulation of the collective will be required during the glide. One exception is that during turns, especially at high speed, some collective may be required to prevent the RPM from climbing too high. Rolling out of the turn, the pilot should put the collective back to where it was before the turn was entered. By performing turns at lower airspeeds, little or no collective will be required.

Failure to maneuver to the point of intended landing

Many pilots get quite proficient at autorotating to the runway at their home airport, but have more trouble when trying to make a specific landing area in the off airport environment. I advocate setting up a (tight) traffic pattern to the landing area, just as is done at an airport. The pilot should figure out the wind, and therefore where "final" will be. Then the pilot should figure out where he currently is with respect to the traffic pattern (is he already on downwind, base, or final?). Once he knows what leg he is on, he can manipulate the length of the remaining legs to arrive on final at the proper altitude. I also suggest a very short final. The longer final is, the bigger the chance is of over or undershooting, with no easy way to correct once the under or overshoot is recognized. Instead, fly a very tight base and time your turn onto short final to give you the desired distance to the touchdown spot. If you are a little low, turn final slightly early. If you are a little high, delay the turn to final, overshoot the centerline somewhat, and use up the additional altitude on base. For gross errors, S-turns or zero (or negative) airspeed may be required. One final rule I have is *never* do a 360 degree turn. You lose track of your approach angle for too long. Instead, if you have massive amounts of altitude to lose, perform a figure-8 pattern on final. This way the spot is always visable, and you can turn back onto final when the angle begins to look right.

Flaring at the wrong altitude

Each helicopter has a range of altitudes it needs to be flared at. The altitude will change from flight to flight based on gross weight, density altitude, wind, and airspeed. Generally, aircraft with higher disk loadings require a higher flare. If the pilot flares too high, the helicopter will stop it's descent too high above the ground to make a safe landing. If the pilot flares too low, he will be forced to level the helicopter (get rid of the flare) too early (to avoid hitting the tail on the ground). The result will be a high rate of descent (which he can probably fix by raising collective) and high forward ground speed (which he can't fix, so he'll slide hundreds of feet).

Assuming we can't always make a perfect flare, which way we would rather err depends on the surface we are going to land on. If the surface is firm and level, some slide probably won't hurt, and we'd rather be a little bit low so we get a nice soft touchdown, followed by a little slide. If the surface does not appear to allow us to slide (swamp or such which will cause the skids to dig in) the flare should probably be a little high to insure we can get rid of all forward speed. We may touch down a little harder, but by being more vertical we reduce the chance of rolling over. One caveat is that human beings do not take vertical accelerations well at all, so if people are going to avoid back injuries, the flare better not be *too* high.

Flaring too aggressively or not aggressively enough

The speed with which the nose of the aircraft needs to be pitched up is related to gross weight, density altitude, wind, and airspeed. Generally if gross weight is high, a more aggressive flare will be required. If density altitude is high, a more aggressive flare is required. If wind is high, a *less* aggressive flare is required. And if airspeed is high, a less aggressive flare is required. Pilots can adjust for minor airspeed deviations by flaring at different altitudes, or with different amounts of aggressiveness. For instance, if the airspeed is 10 knots below optimal, a more aggressive flare will help to make up for this. Of course there are limits to the amount of correction that is possible.

Failure to level the aircraft

Some aircraft land in a slightly tail low attitude, but with many others it is critical to have the landing gear level before touchdown. Failure to do so can result in tail boom strikes and porpoising (where you hit on the heels, and then roll up onto the toes and flip over forward).

Failure to maintain heading during the slide

There are a couple reasons that heading might not be maintained during any ground slide. One is just that the pilot fails to manipulate the pedals correctly, the other is that if rotor RPM gets too low the tail rotor may lose effectiveness. Failure to maintain heading can cause a skid gear to catch and roll the aircraft over on it's side. Most aircraft can perform fairly high speed slides if the skids are pointed in the direction the aircraft is moving.

Moving the cyclic aft during the slide

It's human nature to want to stop the slide as early as possible, but moving the cyclic aft has two problems. One is that the main rotor is probably not generating much thrust at this point, so it won't help much anyway. The other is that flapping is at maximum because RPM is low, and moving the cyclic aft moves the rotor blades even closer to the tailboom. The rotor blades hitting the tailboom is a very real possibility.

Hovering Autorotation Sequence

This first photo shows the Robinson R22 in a normal hover just after the throttle has been closed, removing all power from the rotor system.

This photo shows the helicopter has descended most of the way to the ground, using the energy stored in the spinning rotor system to provide thrust. About this height is where the pilot will raise his collective pitch control all the way up in order to get every bit of available thrust to cushion the landing as much as possible.

This photo shows the helicopter on the ground just after touchdown:

This photo shows the helicopter firmly on the ground, with all the weight off of the rotor system, and transferred to the landing gear. Note that during the time between the previous picture and this picture, the helicopter has yawed significantly to the right. In the Robinson this is characteristic of a pilot who has not rolled the throttle into the override. As the final amount of collective pitch is raised, the Robinson correllator rolls on some throttle and the torque yaws the aircraft while on the ground. This would not normally be considered good technique...

Notice the coning of the rotor blades in this final picture. They make a distinct "V" shape because there is no longer sufficient RPM to hold them down straight.

Ditching

Ditching is when a non-float equipped helicopter must be landed in the water. Ditching might be performed power off if the engine fails, and power on if some emergency makes it necessary to land (such as impending transmission failure).

Power Off

If the helicopter is not within gliding distance of shore and the engine quits, the pilot will have to ditch the aircraft.

Normally the helicopter would enter autorotation. Passengers would be briefed in the use of emergency equipment, and often the doors will be unlatched while in flight. The pilot would normally make any emergency communications possible, and then switch off the electrical power.

A normal flare is performed, and then as the helicopter settles into the water the pilot decreases rotor RPM to minimum and uses lateral cyclic to roll the aircraft on its side. This causes the blades to strike the water and immediately stop turning, so that people are not hit by turning blades while evacuating from the aircraft. Most helicopters will sink fairly quickly since there are not normally large spaces to trap air in a helicopter. This makes it critical that everyone is briefed in how to get clear of the helicopter and get to the surface of the water.

Power On

A precautionary ditching would normally only be performed if some catestrophic problem with the helicopter makes continued flight dangerous. A failing main rotor transmission would be a good example of this. So would running out of fuel. The major difference is that the pilot can come to a hover and offload passengers, crew, and survival equipment. He can then hover away and perform a ditching as described above. By allowing people to egress the aircraft while it is still flying, chances of someone drowning are reduced.

Tail Rotor failure in flight

If the tail rotor fails in flight, engine torque can no longer be countered by the tail rotor, and uncontrolled spinning of the aircraft is a possibility. Most manufacturers call for an immediate autorotation. Some call for a running landing, instead. At higher speeds, most aircraft have enough weathercock stability so that limited amounts of power can be used to stretch the glide or even to maintain altitude until a suitable landing area is reached.

Autorotating

An autorotation is a natural way to deal with an inflight tail rotor failure since it reduces torque to zero. One problem with an autorotation is that it will be difficult or impossible for the pilot to align the landing gear with ground track during touchdown. If the helicopter touches down with forward speed, this could cause a rollover. In calm wind, it is often very difficult to not have some slide.

One possible solution is for the pilot to use the throttle to help align the landing gear. Normally transmission drag will yaw the nose slightly to the left, and engine torque can be used to yaw the nose to the right until it is lined up with ground track. The major problem is that throttle manipulation is tricky, and very slow in a turbine aircraft. Meanwhile, the touchdown phase happens very quickly, giving the pilot little time to use the throttle.

Running Landing

A running landing can be used to land the helicopter at very low power settings. If the approach can be set up with a left crosswind, that will allow even more power to be used without inducing a right yaw. The throttle can be used to align the skids, and because everything is happening very slowly, the pilot has more time to react with the throttle.

One negative to this sort of a landing is that pilots tend to practice autorotations more often than running landings. Touchdown speed in a running landing with no tail rotor is on the order of 10-20 knots. If the pilot makes an error and the helicopter is rolled over, people can easilly get hurt at such high speeds. Autorotations on the other hand tend to terminate at just a few knots, even on a calm wind day. Mistakes which cause a rollover are less likely to cause injury because the speeds are probably lower.

Another way to do the running landing

If a shallow approach is possible, another way to land the helicopter is to make an approach similar to a running landing, but with slightly higher airspeed. When the skids are quite close to the ground, the pilot flares to kill ground speed. As airspeed drops off and the helicopter starts to settle, the pilot uses power to hold the aircraft off the ground, meanwhile he continues to use cyclic to stop all ground speed. The power will instantly start torquing the aircraft to the right, but if the pilot continues to use cyclic to stop ground speed, throttle may be chopped just as ground speed comes to zero. A normal hovering autorotation is then used to land the helicopter. As soon as the throttle is chopped, most rotation will stop, and since the ground speed is zero what little rotation is left is unlikely to roll the aircraft over. This is my preferred method, and normally I get about 90 degrees of rotation before I am able to roll off throttle. The rotation is normally stopped well before touchdown, and I usually induce a little motion in the direction the skids are pointed with the cyclic, in order to get a really soft touchdown. Don't use this technique unless you can get someone to show you how, but if you can find an experienced pilot to show it to you, I think you'll agree with me this is the best way to land sans tail rotor. (that doesn't mean ignore the manufacturer, though).

Engine Fire in flight

This is one of the more serious emergencies a pilot has to deal with. Usually the solution is to get on the ground. Autorotation is normally the fastest way to get down.

Ventilating the cabin

If fumes are present in the cabin, it can usually be ventillated by opening windows or doors or both. If a cabin heater is in use, it would normally be turned off to eliminate the chance of bringing in smoke from the engine compartment.

Turning off the electrics

A possibility is that the electrical system is providing the ignition source for the engine fire. If this is suspected, the pilot might elect to turn off the battery and generator.

Autorotating

An autorotation has two useful characteristics here: it's a fast way to descend, and it prepares for the chance that the engine is going to quit due to the fire. If the engine is still running on short final, I would seriously consider a power recovery to a hover, and then a quick landing and evacuation. The power recovery reduces the chance of messing up on the landing, and ending up rolling over in a burning aircraft. That would really spoil your day. Obviously, if the engine quits, you are going to have to do a touchdown autorotation. In this case, the pilot can go ahead and shut off the fuel in order to reduce the chance of fuel spillage on touchdown.

So far I have not read a manufacturers aircraft handbook which advocates shutting off the fuel if the engine is still running, but I suppose that if I was at extreme altitude, such that it would take quite a while to land, I might consider turning off the fuel in an attempt to put out the fire. This is a pretty drastic solution, however.

Landing

Passengers should be briefed, normally I'd recommend that doors be unlatched, and people should quickly exit the aircraft after touchdown. The pilot should be careful to stress to the passengers that the rotors will be turning, and that people should duck under the main rotor, and avoid walking back toward the tail rotor. I would stay at the controls until the passengers were out from under the rotor disk, to prevent the chance of the rotor disk tipping down and hitting someone. If another crewmember is present, I'd have them escort people away from the helicopter because people are probably panicky, and are likely to run toward a tail rotor even if they have been briefed not to.

Electrical Fire in flight

We normally associate electrical fire with problems in the instrument panel, since that's where most of the electrics are. That's not always the case. Electrical fires are usually identifiable by the smell of burning insulation. Most people are familiar with this smell. Smoke may or may not be visible in the cabin.

Putting out the fire

Most electrical fires will go out once the electricity is removed. How this is done is aircraft specific, but normally you would switch off the battery *and* the generator/alternator. If the fire goes out, the pilot may elect to localize the problem by pulling circuit breakers, restoring power, and then turning each circuit back on one by one. If the fire starts again, the last system restored is probably the culprit.

Depending on the circumstances, this debugging may be better off if done on the ground rather than in flight.

Ventilating the Cabin

Electrical fires often produce noxious fumes and smoke, so ventilating the cabin is usually a good idea. Opening windows, or even the doors, will usually help clear the interior of smoke and fumes.

A word about Rotor Tachometers

There are two common ways to sense main rotor RPM and display it on the Rotor Tachometer. One is to use a mechanical cable which runs from the main rotor transmission (or some other point in the drive system) to the tachometer. The other typical way is to use a "tach generator" which is a small generator attached to the main transmission. Voltage produced by this generator is proportional to RPM, and the voltage moves the tachometer hands. Since both of these systems are independent of the electrical system, neither will be affected by electrical fire or failure.

One exception to this is is the Robinson R22 and R44 helicopter. These helicopters use an electronic tachometer which requires external power to operate. A bypass circuit is installed so that turning off the battery and alternator will not cause the tachometer to fail, but if the fire damanges the wire harness sufficiently the bypass circuit could be compromised (this could also happen to the tach generator system if the wires for it run through the same bundles as the other electrical wires).

Alternator / Generator failure

A failure of the electrical generator is not usually a serious emergency. Most aircraft will fly perfectly well without electrical power. An exception would be a helicopter being flown on instruments in IMC, but these aircraft typically have redundant sources of electrical power.

Checking for overvoltage

Most aircraft have overvoltage protection, to protect the electrical system from damage if the voltage regulator fails. Typically this is a relay which trips if output voltage exceeds some threshold. These circuits are normally reset by turning off the alternator/generator for a few seconds, and then turning it back on. Failure to reset may mean the overvoltage situation is still present, or that the problem is other than an overvoltage condition.

Shedding electrical load

If the power source can not be brought back on line, the next step is usually to shed electrical load in order to preserve battery power. Some aircraft have an *essentials bus*. Essential equipment is connected to this bus, and the other electrical busses are turned off. With one switch, the pilot can shed all non-essential equipment. If the aircraft does not have an essentials bus, the pilot can turn off equipment by hand which he does not feel is required for the safety of flight.

The aircraft I normally fly have about 10-15 minutes of reserve power with a normal daylight load. The more equipment that gets turned off, the longer the battery will last. At night, running the position lights is going to use up electrical power much more rapidly. I would not normally extinguish my position lights, but would plan on a landing almost immediately if the failure occurs at night.

Equipment which I would immediately consider turning off would be transponders and communications radios (after telling ATC that I am doing so), landing lights, cabin fans, non-essential nav radios, interior lights, strobes, etc.

Landing

During daylight, I can probably shed enough load to make it to an airport for a landing. This has the advantage that there may be a mechanic there who can fix my problem. At night, however, I want to be more conservative and shed load, but also pick a spot to land almost right away. I want to have plenty of power to run the landing light to help spot wires and poles on my approach to land. I would be more concerned with getting the aircraft on the ground, than with getting to an airport, and let the mechanic sort it out in the morning.

Hydraulics Failure

Most helicopters use hydraulics to reduce the force needed to move the controls. Usually there is still a mechanical connection. In some helicopters there might not be a mechanical connection, or the control forces may simply be too high for the pilot to overcome with muscle. Generally those sorts of helicopters will have redundant hydraulic systems.

Both the Bell JetRanger/LongRanger and the Robinson R44 have boosted controls with mechanical backup. There are multiple ways such hydraulic systems can fail, but basically you can either have a failure where the entire system stops working, or a failure where a part of the system stops working.

Total Hydraulic Failure

Of the two failure modes, this is probably the easier to deal with. When the failure occurs, the pilot will notice that the control boost is gone, and he will have to fly the aircraft using much more force to move the controls. In the case of the cyclic and collective, he will also usually notice that they are connected, i.e. when he moves one control, the feedback from the rotor system will cause the corresponding control to also try to move. This effect is small and can easilly be overcome.

In a small helicopter such as the Bell or the Robiinson, the stick forces are low enough that the pilot can fly the aircraft with little difficulty. If the pilot has to fly for a significant amount of time before landing, he will probably be fatiqued and it may be difficult to avoid overcontrolling the helicopter while attempting to hover. The aircraft manufacturers generally recommend a running landing instead of attempting to hover in order to avoid this.

Partial Hydraulic Failure

A more difficult failure may be when one hydraulic servo fails, but the others continue to work. This means that his controls are boosted in some parts of their movement, but not in others. Such a failure could easilly result in an aircraft that is not flyable by the average pilot, so Bell and Robinson both provide a switch to allow the pilot to disable the hydraulic system. When the pilot activates the switch, the entire hydraulic system is defeated meaning that the pilot still has to contend with a total hydraulic failure, but at least all the stick forces are equally high, and the average pilot should be able to fly the aircraft with little trouble.

Both the Bell and Robinson hydraulic override systems are "failsafe". That is, it takes an electrical circuit to hold the hydraulic system in the override condition. If the electical system should fail, the hydraulics will continue to be boosted regardless of the position of the hydraulic override switch. The prevents loss of the aircraft electrical system from also causing a hydraulic systems failure.

Hardover Failure

Another failure mode of a hydraulically boosted control system is that one of the servos could be driven to one extreme position or the other by a failure within the servo. This would result in an unflyable aircraft. The pilot can recover from such a failure by turning off the hydraulic system, assuming that the hardover failure did not cause him to lose control of the aircraft.

Short Shaft Failure

Although "Short Shaft Failure" is generally used when referring to a turbine helicopter, a similar failure mode is possible with some piston helicopters as well. This depends on how engine power is transmitted to the main rotor transmission.

In a turbine helicopter, there is generally an output shaft from the engine which is connected through a freewheeling unit to the main rotor transmission. The freewheeling unit is there to allow the main rotor system to continue to spin if the engine stops. However, a failure of the freewheeling unit, or of the driveshaft, or any other components between the engine output and the main rotor transmission input could prevent the engine from being able to turn the main rotor.

Generally the pilot would identify a short shaft failure by his engine RPM tachometer showing a rise in RPM (because the engine is suddenly unloaded) while simultaneously seeing a decrease in his main rotor RPM (because it is no longer being powered by the engine).

The recovery is to treat the failure as an engine failure. The pilot would enter autorotation in order to keep the main rotor turning, and would also move the engine control to idle to prevent a further overspeed of the engine.

Twin Engine Helicopters

A twin engine helicopter could experience a failure of the drivetrain between an engine and the engine combining gearbox, in which case one engine would overspeed, but the main rotor would continue to be rotated by the other engine. It could also experience a faliure of the drivetrain between the combining gearbox and the main rotor transmission in which case both engines would overspeed while main rotor RPM would decay. In practice, the possible failure modes and indications would depend on the particular model of helicopter.

Low Side Governor Failure

A *governor* is a device or system which controls engine power output such that the main rotor maintains a constant RPM. When the pilot raises collective, putting more pitch on the blades, and thus increasing the power required, the governor system would add more fuel to the engine such that the extra power required is exactly balanced by extra power output. The result is that even though power required goes up and down, the rotor RPM remains constant.

Some piston helicopters have a correlation system which is a mechanical way of adjusting power output as the collective is raised and lowered. A governor, on the other hand, uses a closed loop system to sense the RPM and adjust the fuel control to maintain the desired RPM.

A low side governor system failure would be one in which the governor either allows the engine output to go to zero, or to a lower power setting than is required by the current collective pitch angle.

Some helicopters, such as the Robinson, allow the pilot to manually adjust the throttle even when the governor is activated. In this case, the pilot could simply increase the throttle manually by reference to the tachometer, and thus work around the governor failure.

Other helicopters, such as the Bell, have a position on the throttle or flight condition lever in which the governor is in charge of engine power output, and in this position the throttle can not be manipulated by the pilot. For instance, in Bell helicopters, you roll the throttle all the way on to activate the governor. In this position, the throttle is already all the way on, so the pilot has no way of commanding more power than what the governor selects. In a helicopter with that sort of a system, the only choice the pilot would have is to reduce the collective until the proper RPM is attained. This might be at a fairly high power setting or a fairly low one, depending on how the governor has failed. If the governor has failed at a low enough setting, the pilot may have no choice but to autorotate. If the governor has failed at some moderate power setting, it may be possible to maintain powered flight at a lower speed, or with a slow descent.

High Side Governor Failure

A high side governor failure is is just the opposite of a low side failure. In this case the engine is being commanded to put out too much power. The indication to the pilot will generally be high engine RPM and torque, as well as high rotor RPM.

The Robinson governor can also be overridden in this situation by rolling the throttle to a lower power setting, thus the Robinson can easilly be recovered from a high side failure. Generally the pilot would just turn off the governor in this situation and rely on the throttle correlator (mechanical) to help him maintain proper RPM.

Most turbine helicopters will allow the pilot to retard the engine power output using the throttle or power lever. Thus a high side failure can generally be handled by rolling off throttle or pulling back on the engine condition lever until RPM is restored to the green range. In an extreme situation the pilot might have to turn off the fuel in order to shut down the engine.

Runaway Clutch

This failure is unique to the Robinson helicopter design. The Robinson has a system which automatically maintains the correct tension on the engine drive belts. It does this by having sensors which detect the tension in the belts, and an electric motor coupled to a jack screw which elevates the upper sheave (pully) to increase tension on the belt.

The direction that the motor runs is controlled by the cockpit clutch switch. In the engaged (flight) position, the motor will only run forward, increasing the tension on the belts. Thus it will never decrease tension on the belts in flight.

If the belt tension sensor fails, the clutch system may run the motor in an attempt to increase what it believes is a low belt tension condition. In this case, there is a real danger that the belts will be tightened so much that they will break.

The POH calls for the pilot to monitor the automatic clutch system while in flight, and if he sees the motor run for more than 7 or 8 seconds, to pull the clutch system circuit breaker. This will cause the motor to stop running, and the upper sheave will stop in its current position.

Settling With Power (Ring Vortex State)

Settling with Power, more correctly known as Ring Vortex State, is a condition where the helicopter is at low airspeed and is descending down into it's own rotor downwash. There are three conditions required for it to be generally possible:

- Airspeed below Effective Translational Airspeed
- Engine/Rotor developing considerable power
- Descending at approximately 300 ft/min or greater

Airspeed Below Effective Translational Lift

If the helicopter is moving forward at enough speed to be in Effective Translational Lift, the rotor is not moving into it's downwash, but into clean air. Thus it is not possible for Ring Vortex State to occur at airspeeds higher than ETL (generally about 10 iknots).

Engine/Rotor developing considerable power

Below about 20% engine power, the helicopter is not developing enough downwash to generate a vortex of significant size. Thus settling with power is generally associated with moderate to high power settings.

Descending at approximately 300 ft/min or greater

If the helicopter is descending at less than 300 feet per minute, it tends to stay above the downwash and will not enter ring vortex state.

Recovery from Setting With Power

There are two methods to recover from the ring vortex state. The first is to enter autorotation. The helicopter will fall through the column of descending air and eventually reach clean air. This is not generally used as a recover method, because it requires an extreme amount of altitude to effect the recovery.

The second, generally used method, is to gain airspeed. Normally this would be forward airspeed, but airspeed to the side or to the rear would work as well, as long as the helicopter moves into clean non-disturbed air.

Most texts recommend lowering of the collective as part of the recovery. This is because in a fully developed ring vortex state the rotor may be operating at near stall angle of attack and this can reduce control authority. By lowering collective at the same time as moving the cyclic (usually forward) the pilot can get the nose down and the helicopter accelerating into clean air.

As soon as the aircraft is in clean air, the pilot can add power and raise the nose to gain altitude. It is important for him to not raise the nose so far as to lose all the airspeed he has gained or he could find himself back in the ring vortex state.