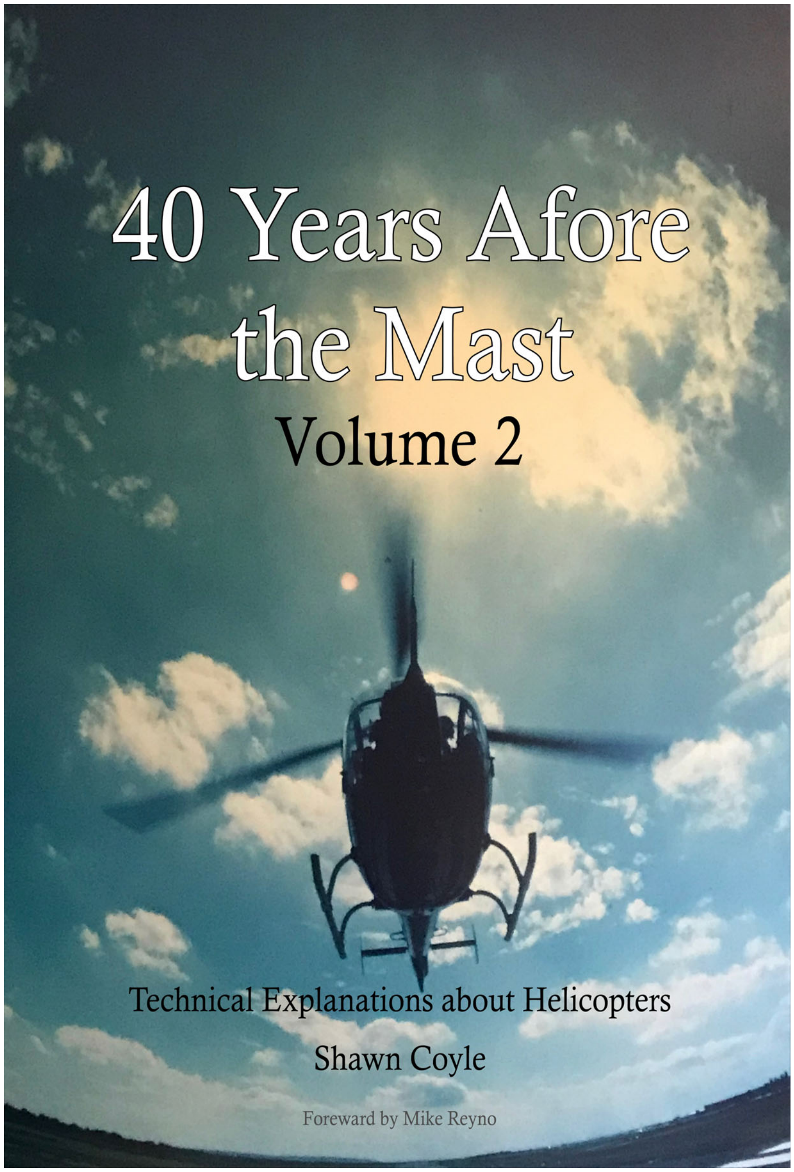

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Weight and Center of Gravity

Vertical

Not Sure When!

Comment: The issues of weight and balance can present not only physical limitations and issues in helicopter flight, but legal ones as well.

Weight and balance is a subject in the helicopter world that is not as well understood as it should be. There are in fact two separate and distinct parts to the problem of weight and balance.

Weight is an obvious performance issue, even if we ignore the difficulty of getting the information we need from civil performance charts. For those helicopters that operate over a wide range of altitudes in a single mission, the effects of altitude and temperature are nearly impossible to take into account as far as weight goes.

Understanding the Issue of Weight

To truly understand this issue, two separate charts are needed. One is a chart of power required to hover versus weight and density altitude, at a variety of heights above ground. There are lots of lines on a chart like this —military helicopters all have them. The other chart needed is engine power available versus pressure altitude and temperature.

In the civil turbine helicopter world, the engine power available chart exists (sort of – the engine power check chart), but the power required to hover chart does not (sadly). Pilots are not easily able to determine performance if they are going to try hovering at a location a lot higher or hotter than where they started from or at a height other than the single in-ground-effect height given in the flight manual.

Exactly how much do the helicopter, crew and equipment weigh? My memories of emergency medical service (EMS) flying include the med crew telling me, as they hoisted the lucky winner of the helicopter trip on board, that they estimated he weighed 240 pounds. As there was a legal requirement to calculate weight and center of gravity (CG) before taking off on the patient leg of the trip, it took an additional moment or two to make the calculation and record it on the flight log. (We must remain legal at all times!)

This brings up a good point. Do we use nominal weights or real weights? Nominal weights were developed for use by the airlines to save actually weighing all the passengers and their baggage. Now, an average weight may work out well for a load on a 747, but not for a helicopter hauling around firefighters and their equipment. Please use actual weights! The payloads of most helicopters are small enough that an error on the wrong side of weight can put you in trouble from a performance, as well as a legal, point of view.

Understanding the Issue of Balance

Weight, of course, is only half the equation. We seldom have to pay the same degree of attention to balance as the fixed-wing world does, because we don't depend on the moment arm from the horizontal tail to balance all the moments and provide control. In a fixed-wing airplane control becomes quite entertaining with the center of gravity aft of the limits. With the CG too far aft in a helicopter, the problems can range from too much stress on some dynamic components to running out of forward cyclic. And the opposite for a CG that is too far forward.

CG has three positions — two that we worry about, and one that's nearly impossible to calculate and seldom affects things. The two CG positions we worry about are longitudinal (fore-aft) and lateral (side to side). The one we don't worry about is the vertical position (more on that later).

Every pilot should be able to calculate CG using any of the different methods but most importantly by using the one included in flight manual for the helicopter being flown. This includes manually calculating it manually with old fashioned adding, subtracting, multiplying and dividing. The CG should be calculated every flight, whether there is a legal requirement or not. And I mean both longitudinal and lateral CG, unless you're absolutely sure you have a laterally balanced load all the time. For instructors, have your students calculate the wt and CG every flight – even if you know it's not a problem – it builds good habits for later in life.

What is not often understood is that unless the helicopter has an extremely simple fuel system (one tank right under the CG), it may be possible to put the CG out of limits as fuel burns off. Check your flight manual!

Calculating Center of Gravity

Anyone with any experience in spreadsheets can make up a thorough CG calculator that can even show the CG as the fuel burns. (See the diagrams on p.xx. If I can do it, so can you…)

Away from the office, though, calculating CG is a pain. We don't have the equipment to do it easily in the cockpit. Even the mechanical and electronic gizmos aren't easy to use with one hand. And, how do you not keep one hand on the cyclic when you're loading and unloading passengers with the rotors turning?

There are programs for most smart phones/PDAs to calculate CG, and they are worthwhile. Another trick is to pre-calculate the extremes of weight you'd accept. This ensures you stay within the CG envelope. Minimum and maximum fuel should be the starting points to calculating the maximum and minimum cargo/passenger loads. If you're doing fair ground rides, for example, this can keep you out of trouble.

Longitudinal and Lateral CG

Why do we worry about longitudinal CG? Aside from control margins and stresses on dynamic components, the longitudinal CG position will affect the directional stability of the helicopter. With an aft CG, the moment arm from the vertical stabilizers and tail rotor is shorter and has less effect at keeping the pointy end forward. Sail boat people talk about the keel area ratio — the hull area ahead of the keel (CG in our case) must be less than the hull area behind the CG or the boat will want to point backwards…

We should worry about lateral CG because of the need to hover with winds from the side (i.e., you might run out of lateral cyclic.) We also should worry about lateral CG because of the effect it has on drag in forward flight.

How's that again, you ask? If you slavishly fly with the ball in the center all the time, a large offset in lateral CG will generate a lot of sideslip, which is not the most streamlined way to fly. While some helicopters have slip strings and can avoid this problem, if all you have is a slip ball, then you need to note the slip ball position in an into-wind hover and keep it there in forward flight.

Lateral CG isn't just an issue for a load that just sits there. It's also an issue for a live load, such as police officers jumping on or off the skids. Next time you stand on the bathroom scale, do a mild hop up and down and see what that does to the weight displayed. It's a pretty remarkable difference for even a small bounce. Now imagine that happening on the skids of the helicopter as two large officers jump on or off the skids at the same time. If you have the flight manual handy, calculate the effect that has on the CG, and you'll be very unpleasantly surprised. Although, not as surprised as the pilot who couldn't stop the helicopter from rolling onto its side was, though. The folks in the picture obviously got on symmetrically!

VERTICAL CG

When thinking of vertical CG, consider carrying a load of gold on the floor versus an empty helicopter. The gold on the floor will obviously move the vertical location of the CG down significantly. Normally, there is little change in the CG's vertical position, but if you have a lot of surface area below the CG, such as fixed floats, a high CG (when the helicopter is empty) will have a different effect on the handling than when the CG is low. This is, if you like, a vertical keel area ratio. In other words, if the side area below the CG is greater than the side area above the CG, then any side wind will cause the helicopter to roll toward the wind. In forward flight, the side wind is sideslip, and the effect it has is called a dihedral effect. If there is a sideslip when there is too much surface area below the CG, the helicopter will roll into the sideslip — not a good thing.

Underslung loads move the CG down considerably, and can have an adverse effect on handling in forward flight. Moving the CG down also complicates normal control, as the rotors are being used to move something a long way from the normal CG.

Finally, there is one last point to consider about weight and center of gravity. If you exceed the limitations of the flight manual, the certificate of airworthiness (and probably the insurance coverage) becomes invalid. Always remember, there are legal implications as well as physical ones.

Weight and center of gravity are important for handling, and weight is very important for performance. Pay attention to both and you'll stay out of a lot of trouble!

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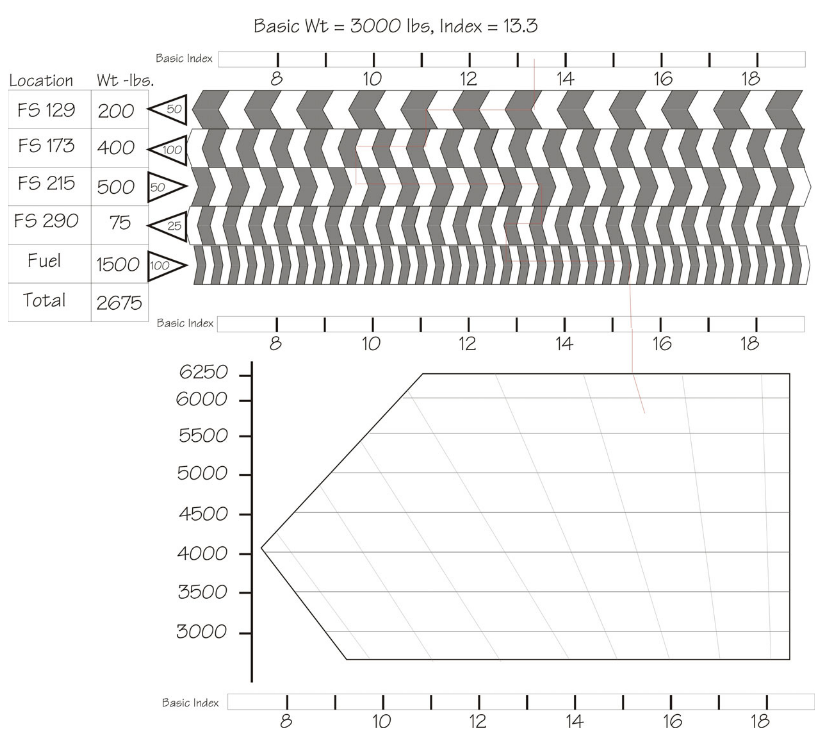

Figure 22-1 **Arrow- Type CG Chart**

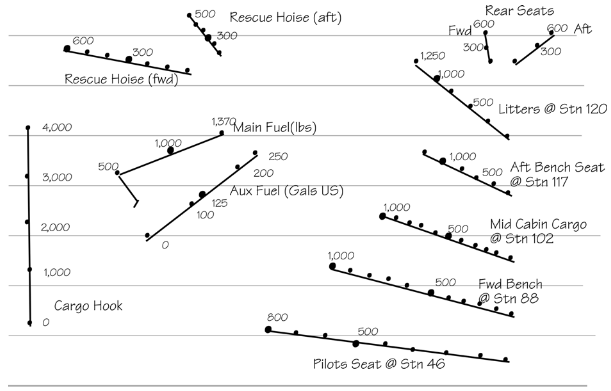

Figure 22-2 **Sliding Part of cg-wt calculator**

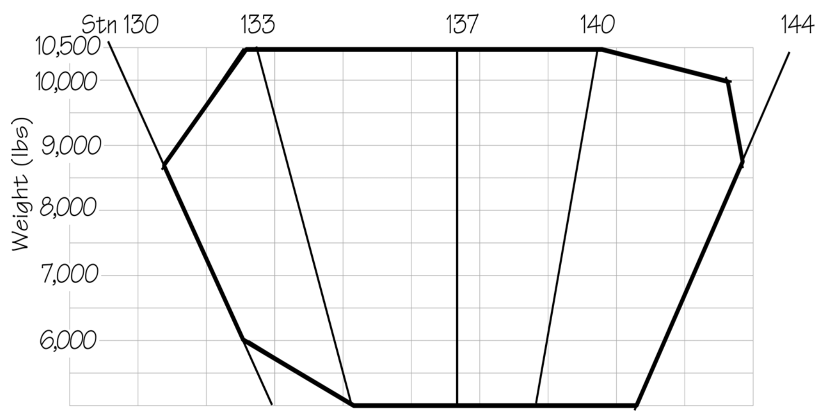

Figure 22-3 fixed **part of cg -wt calculator**

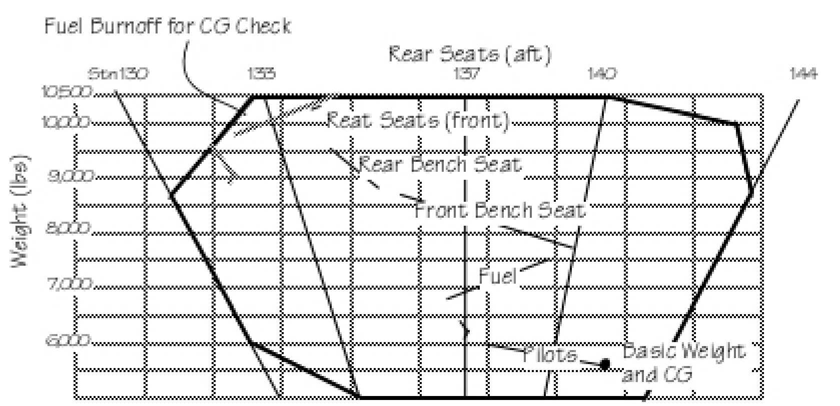

Figure 22-4 **Combined Result**

Cargo Hooks and Load Cells

Vertical February / March 2012

Comment: Although weight sensors and lift charts are standard fare on tower cranes, the aerial variety still sadly lacks these seemingly simple but very essential elements.

If you've ever been around a downtown construction site with those marvelous self-erecting cranes, or any other place where things are lifted off the ground by mechanical means, you'll likely have been impressed by the ability of these devices, but probably missed an important part of their safety. Just looking at the booms on one of these cranes, however, it should be obvious that the amount of weight that can be lifted at the end of the crane's reach will be less than that close to the crane's tower. To make sure that these limits are respected, these cranes incorporate load cells on their cargo hooks, as well as complex tables of what can be lifted at what distance from the crane's tower. On the smaller end of the industrial lifting scale are the forklifts that busily buzz around warehouse floors. Even they have limits on what they can lift to what height.

What has this got to do with helicopters?

Well, helicopters are often used as aerial cranes, lifting a wide variety of loads in locations that ground-based cranes can't get to, or operating in areas that are completely inaccessible to ground-based vehicles. Let's face it, if it could be lifted by a ground-based crane, it would be a lot cheaper than using a helicopter. Yet, even with the cost and value of the helicopter as an aerial crane, few, if any, helicopter operations are required to have load cells on their cargo hooks. In fact, I don't know of any regulation by any civil authority that requires a load cell to be included (and operational) when a helicopter is lifting underslung loads. (The presence of load cells that feed into the flight data recorder (FDR) on some Russian helicopters leads me to believe Russia may have a requirement in their rules somewhere, but that's another story.)

Understanding the Need

Before getting into the reasons why we should have them fitted (and their information recorded into any FDR), it's worthwhile looking at why we've ignored the problem up to now. To do that, we have to reach way back into the mists of helicopter time, to the early machines — the piston-engine ones that could lift themselves and a relatively small payload into the air at low altitude on a cool day. The cargo hooks on these early ships were often connected directly to the transmission, but the performance of these helicopters was so limited that anything that might be hung underneath them was such a small fraction of the total weight that the external load couldn't do much structural damage to the airframe, even after lots of repetitions. Also, the ship's structure was pretty well always visible, so if it did sustain any damage, it would be readily noticed.

Things have moved a long way since then: turbine engines, advances in structural materials, and advances in rotor blade aerodynamics have given us helicopters capable of lifting much heavier loads, especially when considered as a percentage of the empty weight of the helicopter. Cargo hooks are now connected to the transmission via complex structural elements in the fuselage, and these are often hidden from direct view. However, other limitations in the airframe, such as torque or engine limits, do not always respect the load-lifting capability — in other words, the engine and transmission are often capable (at low density altitudes and air temperatures) of producing more lift than the structure can safely handle.

One example of this limitation vs. capability situation occurred with the Puma fleet of the Royal Air Force. These helicopters had only a collective pitch angle limitation in the hover (as opposed to using a torque meter, which the clever among you would say wouldn't have made any difference, and you'd be right. But that's another story…) — and no load cell on the cargo hook. When