Material Selection- Part 5 of 11

So, this part we will be getting into probably one of the most engaging topics around materials selection. Just a reminder keep it respectful and positive.

So, before we get into the meat of the discussion here are a few factors that I always consider with regard to material selection. No matter which piece you choose or whether it's an experimental or certificated aircraft you should always have answers for at least these questions when selecting materials. Many experimental aircraft use components that are from certificated aircraft. Many people select materials based primarily on cost alone, while it is one method, it exposes the pilot and others to a large amount of risk. I personally review each component with these criteria and with a specific client to rate their importance. Sometimes in the course of reviewing these factors, it may cause you to reconsider your design. Especially, if you find that any component causes you to answer yes to item 1. Many of these factors will be needed to determine what needs to be inspected and how often in your instructions for continued airworthiness as well as your limitations in your flight manual.

1. Safety Critical Part or characteristics - If this single part fails, would it cause complete loss of control of the aircraft, or immediate catastrophic loss? (example, LPG tank, crown ring)
2. Design life - how long should the component last? (could be calendar or flight time)
3. Weight - How important is the weight of the component? You could in theory use Nomex/Aramid blend for the entire balloon, but the weight difference may require you to change the volume of the aircraft significantly to lift the weight of the system. When designing or selecting materials, many engineers use a simple formula to estimate the overall weight.
   Example for every 1 lb. of useful load, the aircraft must weigh 3-5 lbs. to support the extra structure, fuel, lift etc. Lighter Than Air category this formula still applies but it's a fraction rather than a multiplier like large aircraft. For example, think of a simple 38k cuft envelope at ISA sea-level one could reasonably expect to generate 600lbs of lift. The system I just built weighed about 140lbs thus useful load is about 360 thus for every 3.3 lbs. of useful load 1 lb. of structural weight is required. If you do the same concept with a 90k balloon the number gets a bit smaller. At about 1.5 to 1 but remember 90k typically uses heavier grade materials for commercial operations.
4. Durability - I can use lightweight materials but if they get damaged quickly it can be more expensive in maintenance cost of operations than in cost of acquisition?
5. Limitations of the component - (example, in general nylon experiences permanent damage over 275F if your design requires you to operate at 400F you will not be flying very long)
6. Acquisition cost - There are extremely advanced materials and processes that would allow us to reach 5lbs useful load at less than 1 lbs. however the cost would be prohibitive to most experimental builders.

   Imagine trying to balance a dinner plate full of food on top of a broom stick every time you take a bite (cost, weight, durability) you have to rebalance. This is the process you will experience. It's iterative, and sometimes maddening but to complete a final design. I refer you back to your original mission profile, when you can meet your

mission requirement at a safety factor, cost, and design life that you can accept. Lock the design and move forward. But if you have not made decisions on your flight missions your design and materials selection will continue spinning out of control.

Fabric

Weight, when you hear 1.4oz 0.9oz or 45gsm what they are referring to is the actual weight of the fabric in ounces or grams per square yard or meter. This will play a very big role in the overall weight, durability, and life of your system. Some folks want hyperlight systems that the entire weight is less than 50 lbs. It's possible, but comes at a sacrifice of durability, cost and sometimes life of the system.

Coating, any woven fabric has a basic porosity that allows fluids (liquids or air) to pass through them by applying an external coating, impregnating the fibers, we can improve the porosity for our purposes by making the fabric less porous or resistant to flow. The most common forms of doing this is via silicone or polyurethane coating. Now this is a manufacturing subject that could be discussed for weeks on its own but the basic differences are heat tolerance and durability. Some factors to consider are how many coats, and what type of coating. In general, both are very widely used. I won't get into the debate of silicone vs PU coating except that I have used both, and I personally prefer PU because it seems a bit lighter and more durable, but that is based on my personal experience. I will say that some Fabric MFGs provide specs of their materials BEFORE they are coated like weight and tensile strength, be sure to ask for the as delivered specs or conduct your own tests with a 3 party or yourself before making a final decision.

Core Fiber- The two most common are nylon 6 or 6/6 and Polyester, there are some exotic materials but they are extremely expensive and can be very difficult to maintain with regard to repairs. So, for this group we will focus on the common fibers. Nylon generally has a higher initial tensile strength, but degrades with time, exposure to heat and water. Polyester has a most stable and less drastic degradation with heat but can be heavy and more difficult to retain its color. Again, not advocating one way or the other just sharing my experiences.

Patterns and Fills - These are about as abundant as wild flowers, with honeycomb, triple square triple diamond, no pattern each has its own benefits and consequences. You may hear of a term call denier, this refers to the diameter of the thread used to make the fabric. As you can imagine the higher the number the larger the diameter and thus the stronger and heavier the fabric. In balloon fabrics the average is between 50d and 200d.

As an example most standard balloon fabric is around 70-100d, some of the current manufacturers use 200d at a weight of 3-4oz/sqyd as you can imagine this can get heavy, but holds up well to very high frequency use in desert, tree laden and rocky environments.

Webbing and Cables

The best advice I can give you with the literally thousands of options for webbing and cable options is that Mil spec is the easiest to follow. Since the webbing will carry much of the load like your bones, most designers consider webbing by tensile strength. From a static load perspective if you have let's say a 750 lb. max gross weight and 16 gores like the plans I shared you could reasonably divide the load

amongst the 16 cables. Thus, a load that would probably not exceed 47lbs at any point from the crown plate to the lower cable eye. The problem is dynamic loads. So typically, you will want a higher safety factor. Can you choose 50 lb. tensile strength well yes, but should you, not if you are taking into account risk and redundancy. The plans and materials we selected all had minimum break strength of 500lbs, this was to account for a safety factor of 5 which is an industry standard in any lifting component over the working load limit (WLL) plus any dynamic loading like drop lines, tethering or in worst cases loss of some load bearing legs due to collision or failure. In the plans I shared using the materials I specified, a person could lose 75% of the cables or load tape connections and still survive as long as 2 attachment points were maintained. Do not get me wrong it's not something you want to test, but it's peace of mind that losing 1 load tape or cable is not catastrophic.
It also gave us the option to use lighter weight load tape. We chose a ¾ in wide ribbon tape, which is approx. 0.1oz/yard this is very different from a ride balloon which typically uses 1in webbing or tubular webbing with 0.5oz/yd weight. Clearly the durability is a factor as well thus we took care in critical areas like the cable attachment points to protect the loops with a Nomex sleeve.
Another consideration in cables is the type and material, certainly you can use non-metallic or metallic. We chose an SS aircraft grade ultra-flexible 7x19 cable that is 1/16” diameter. The reason we chose metallic was the inability to gimbal the burner. 7 by 19 means 7 groups of 19 strands of stainless-steel wire(see the photo of a cross section) it is a very common and industry standard for any tension-based cable in the aircraft industry and has a wide variety of termination options.
With regard to thread, we used type 69 nylon twisted and bonded. We chose white thread to go with the black load tapes so that inspections are easily done at mfg and on condition. Polyester is available as well, it's amenable to selecting your fabric thus treat your thread accordingly.
In relation to selecting hardware. We used all SS hardware to reduce the possibility of galvanic corrosion. This is important because air which almost always has humidity acts as an electrolyte between two dissimilar metals. One becomes an anode the other a cathode. The components can corrode over time just because the metals are different. We even chose the same grade of SS 304 vs 316 and a quick note if you choose to use SS as we did, you must choose tin plated copper sleeves rather than nickel plated. Specifically, because of corrosion resistance. You can also in some cases use aluminum hardware which is much lighter, however, be sure to check that you are purchasing hardware that has a load rating typically in WLL Lbs. or KN. As a reminder WLL is usually 5x less than actual break tension. Two very different things. If you are not sure, ask the supplier to provide the technical spec sheet and one of us here will gladly help you sort out whether the component is appropriate for your application.
Some folks choose Kevlar based load cables or even no-load tapes, to save weight. Again, these are all possibilities that you must decide based on your mission and system criteria. There are perfectly safe combinations which use this technology, however the mission profile and design of the plans I shared favored the materials I specified.
With regard to Nomex, Kevlar, aramid-based fabrics. With most “hoppers’ or personal LTA aircraft, burning the mouth and or first panel is a concern a bit more than larger balloons because a, the diameter is smaller, b the proportion of damage

can be much more critical, and c the burner typically does not gimbal or articulate to allow the pilot to “aim” the flame. We chose to use a 44in tall Nomex/aramid blend due to weight and safety. Combined with a 6ft tall and 8 gore wide scoop of the same material. Our scoop is pilot replaceable with no sewing, using a Velcro based attachment system interlocking loop system. The scoop is optional for flight in our case but since the proximity is close to the blast area we prefer it be Nomex/aramid. The blend we chose was 4oz/sqyd. Obviously, there are heavier materials that have a higher burn tolerance, but cost and weight were factors.

For control lines we used polyester sheath nylon core double braided rope. We chose ⅜ diameter (10mm) because our experience has been that anything smaller is quite difficult to grip with gloves and cause the pilot to wrap the cord around their hand to be able to pull the vent. You can imagine the risk that creates and frankly some people just do not have the grip strength for a small diameter cord. We did choose solid red so that future pilots would be able to easily identify the function of the cord. There is no FAA standard but it’s pretty common accepted practice.

Lastly, I will leave you with quantities, nearly every manufacturer uses an under over tolerance. 10% +/- are the most common tolerances that I have seen so keep this in mind. You may order a 100-yard roll but only get 90 yards of usable fabric. Same with webbing. I oversize the order by 10% and usually give the overages to the client for repairs. It’s my personal policy but not all companies do this, some use the materials for other projects. I am not saying it’s wrong or you are being cheated as I don’t see an issue overall as long as you know before you agree. It’s just something else to consider if you are getting help.

Again, it’s a lot of info to take in and decipher, there are loads of people on the group that will help so ask questions