Selecting Suitable Chamber Clothing Materials

A Review of the Relevant Considerations

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DESCRIPTION

Much has been written about, speculated on and even mandated as to what clothing materials are suitable for use in a hyperbaric chamber. This article provides some of the factual and practical considerations when selecting materials for chamber clothing.

All clothing fabrics burn, especially in the presence of elevated concentrations of oxygen. There are other considerations to take into account, including static-electricity control, comfort, fit, functionality, appearance, soil-resistance, laundering suitability and even control of dedicated clothing within a department. However, the overriding consideration remains fire safety and this largely affects the final decision.

COTTON FABRIC

As still evident in many hyperbaric standards and guidelines, cotton has been the material of choice. This is largely based on perceptions that cotton burns slower, does not generate static electricity, does not release especially toxic combustion products and does not melt onto human skin. However, this is only partially true and the fire performance of cotton needs to be reviewed in more detail.

The main factors that render cotton more or less burnable are the density of the weave, the thickness of the material, the presence of a fluffy or loose pile and the individual fit on the person. Being an open-cell (i.e. porous) material, cotton does not retain oxygen once the environment changes. Lastly, cotton does not promote a build-up of static electricity, rendering it less likely to serve as a source of ignition energy.

In comparing similar materials (in terms of weave, thickness and fit) cotton takes less time to ignite, as indicated in the table below.

CLOTHING MATERIAL	TIME TO IGNITE*	NOTES
Rayon	3.0 sec	A cellulose material
Cotton	4.8 sec	A cellulose material
Denim	5.0 sec	Dense cotton weave.
Silk/Wool	7.6 sec	Protein fibers. Does not ignite easily (naturally fire retardant) unless the fabric has a loose weave or flammable dyes are used. Poor static- electricity control.
50/50 Polyester -Cotton blend	9.2 sec	Combination does not burn like either fiber. Dyes can increase the flammability. Closed cell structure (rather than open cell structure) will ignite and burn more easily.
Polyester	10.0 sec	Fibers do not ignite easily but burn at a high temperature when ignited. Melting residue in certain polyester materials will stick to human skin leading to deep burns.

**"Time to ignite" is the time taken to get the material, held against a flame, to ignite. The test method is not as important as the relative difference in performance of different materials.*

OTHER FABRICS

In addition to cotton, there are two additional, practical options available: (1) a "suitable" blend of cotton and synthetic (polyester) material, and (2) new generation fire-safe materials, such as a blend of viscose* and a natural fiber (an example of which is a fabric made of wool and viscose – used to produce children's nightwear).

The "fire-proof" materials used by firemen contain fibers manufactured from glass, aramid (e.g. Nomex™ and Kevlar™), novoloid (e.g. Kynol™) and Saran™ (a range of polymers made from vinylidene chloride). These are generally regarded as not-suitable for daily prolonged use where the clothing is required to be laundered after each treatment. These materials are also significantly more expensive than other options.

Reviewing the intrinsic properties of these materials provides additional, relevant information, such as a comparable measure for determining flame resistance called the Limiting Oxygen Index or LOI (refer to the table below). This measure indicates whether material is appropriate for hyperbaric operating conditions, because these indices represent the minimum concentration of oxygen required at the *ambient* environmental pressure to ignite the materials. The higher the LOI value, the less likely the material will ignite, assuming that the same conditions prevail. Once again, it is the relative scale that is important rather than the absolute values.

Fiber	LOI[1]
Kynol™ (A novoloid fiber)	30-34
Aramid (e.g. Nomex™)	28-31
Wool	24
Polyester (PET)	22.7
Cotton	19

In essence, the term *flame resistance* when applied to the use of clothing in hyperbaric facilities, should read as "*more time to act*"; a precious commodity in the event of a chamber fire.

ISSUES TO CONSIDER

As with most decisions, multiple factors influence the final choice. In determining the most suitable, the safest and the most compliant product, the following decision factors should be considered and prioritized according to actual situational requirements and existing risk factors:

- Lasting flame resistance. Some materials lose their flame resistant properties with repeated laundering.
- Tight weave construction. A material with a tighter weave is generally harder to ignite.
- Control of static electricity.
- Reasonable protection against radiant and convective heat. Thick tightly woven fabric provides a physical barrier between the person and the source of heat. Thin loosely woven fabric will allow infrared radiation and hot gas from a nearby heat source to injure the person.
- Comfort. Breathable and irritant-free for most patients.
- Durability. Will not tear or wear out with repeated use and laundering.
- Soil resistance. Should not stain easily.
- Color fastness. Unique colors or markings are sometimes used to identify hyperbaric linens. These may fade away with repeated laundering.
- Acceptable cost.

In the author's opinion, the choice is between:

a. Cotton, traditionally recognized as acceptable risk. It is comfortable, affordable, reasonably durable and has anti-static properties; but not necessarily the best combination of all factors;
b. A cotton/polyester blend in which the polyester content does not lead to melting causing it to adhere to human skin (Trevira™ being a good example of such a polyester), and where the fibers are open-celled, so they do not retain oxygen after a treatment; or
c. A wear-friendly and fire resistant product such as a wool-viscose blend. Availability and cost of this option are the primary issues.

The author has three personal opinions regarding clothing not related specifically to the material, but do having a bearing on fire safety.

a. It is preferable to select clothing that can be removed relatively easily without having to be pulled over a person's head. Garments that can be removed easily in the event of a fire will result in less severe burns, or possibly avoid burns completely. It has to be accepted, however, that the various fixtures such as buttons (which tend to come off) or ties (which tend to result in modesty issues) are not ideal.
b. Pockets should not be installed in any chamber clothing. Pockets may be used to carry contra-band into the chamber.
c. It is preferable to have tight-fitting garments. The more tight-fitting the garment, the lower the flame spread rate tends to be. In the 2009 Florida fire, the least burned surfaces of both victims were the areas covered by tight-fitting undergarments. The undergarments happened to be synthetic.

What about tie-strings versus elasticized waist bands? In theory, loose pieces of clothing will ignite more easily; yet elasticized materials contain especially hazardous synthetic materials. The best path to follow is that of full analysis and selection of materials that are most suitable (e.g., a tight-weave draw-string, or an elastic material with natural rubber and fire-resistant fiber). However, in both cases, as long as these materials are kept away from direct heat exposure and are surrounded by other known fire-resistant materials, the actual additional risk is not significant.

COTTON/POLY CONTENT

A common requirement specified in hyperbaric standards is the material should be a suitable blend of cotton and polyester. What percentage of polyester is the right amount? The answer lies in the data that can be retrieved to validate the decision: (1) the time to ignite is longer than that for

* Viscose is a natural polymer made from wood pulp, often referred to as Rayon, and commonly referred to as a semi-synthetic fiber.

cotton; (2) will the burning product leave a residue that adheres to the skin causing further burns; (3) is there any fire-resistance data available on the product or will this product in fact burn more rapidly than cotton in an oxygen enriched environment; (4) is static electricity a significant environmental issue; and (5) is a suitable blend actually commercially available. Where there is doubt and where the answers are not easily found in literature or manufacturer's specifications, the material should be tested.*

STATIC ELECTRICITY

No discussion on the suitability of clothing would be complete without a word on static electricity. Static electricity is a natural occurrence, more prevalent where humidity is very low, caused primarily by friction, and resulting in the discharging of 3000V+ sparks - sometimes between unsuspecting personnel or patients and any grounded object (like the chamber). In addition to being an unpleasant surprise, it is a possible ignition source. In general, cotton tends not to produce a significant static charge, whereas polyester-containing materials are more inclined to do so. There is an almost direct relationship between the polyester content and the amount of charge. Therefore, additional controls may be needed where static is a known environmental issue, and these apply to both the inside and the outside of the chamber. These could include grounding straps (which may be wrist, heel or shoes-based); washing with a suitable fabric softener or spraying materials with a 30:1 dilution of water-to-softener; applying a suitable, liquid-based (not aerosol-based) anti-static spray (these are usually produced using de-ionized water, chemicals but also alcohol or ethanol, implying that caution in their selection is needed); or using grounding mats located at key places (especially at the entrance to chambers).

FLAME-RESISTANT TREATMENTS

These products are commercially available and relatively successful, especially where applied to natural fibers. However, these products wash out, requiring frequent re-application. Also, it is not possible to determine how much fire-resistance is achieved from applying the product or how much is lost over time. If flame-resistant treatments are used, strict compliance with manufacturer's care and cleaning instructions must be maintained.

CONCLUSIONS

It is evident that there is no cookie-cutter answer to the best choice of materials to use in a hyperbaric chamber. This article has outlined the underlying issues on clothing materials in chambers, highlighted the important aspects and provided a basis for reaching an appropriate decision. Informed decisions are good decisions, but none are perfect.

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* Testing is the only secure way to ascertain the flammability of the blend, as the flammability characteristics of a blend are different to those of the individual fibers.[2] However, the author is not suggesting that testing should be done by users in their chambers. A relevant scientific standard such as ASTM D 1230[3] needs to be followed, making this a complicated and generally limited option, available to those with access to such testing facilities.

Decisions should be made on the basis of sufficient knowledge of the material and an appropriate prioritization of the relevant decision factors based on the actual risk elements present at the facility. Each facility will have different requirements, criteria and constraints; but the typical factors listed in this paper should cover the main considerations that would apply. The decision-making process should be recorded in writing, and maintained with the facility's documented safety program.

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