C62 Heat Damage to Cotton Fabrics as a Clue to the Conditions That Produced It

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After attending this presentation, the attendee will learn about the variables in producing heat damage to textile materials, specifically cotton, and the observed stages of damage in actual burns.

This presentation will impact the forensic science community by offering the beginnings of a tool for correlating observed residues from textiles damaged fires and other heat sources with the conditions under which the damage was produced.

Textile fabrics from clothing, rags, and home furnishings are often damaged at fire scenes and by other sources of heat. It would be useful if the conditions that caused the damage could be inferred from the type of damage observed. The focus of the existing forensic literature is on the identification of fabrics and fibers that have been damaged, with several papers by Jolanta Was-Gubala and colleagues that do treat the effects of flame vs. radiant heat and another treating scorch damage from vapor cloud explosions. Forensic pyrolysis studies, even of fabrics, tend to focus on pyrolysis products that appear in vapor phase samples, where the interest is in the textile pyrolysates as contaminants. Textile flammability literature treats factors affecting ignition temperature and flame propagation, but not the burn residues themselves. There is also a body of literature treating charred materials as energy sources, and pyrolysis as a way to dispose of wastes. However, little information is available correlating the thermal damage itself with the variables in burning and heating processes. This is the focus of our study.

The processes by which heat results in fabric damage can be affected by several types of variables: the heat source (does it continue to produce heat, or is it removed after fabric ignition); the type of heat (flame, radiant heat, convection, etc.); the temperature, amount and duration of heat; the type of fabric (fiber type, thread and fabric structure, etc.); ambient conditions (temperature, humidity, air movement, oxygen-rich or oxygen-poor); and interactions between heat source and fabric (is the heat-source a fuel that continues to burn along with the fabric, or does the fabric self-ignite and burn with the initial heat source removed).

The authors decided to begin our study with cotton. It is the most commonly encountered clothing fabric type, is highly flammable, and typically sustains a flame after an ignition source is removed. After several experiments with cotton swatches that reflected variables in fabrics, including type of weave, nap (fuzziness), and loft (tightness of weave) of the fabric; and horizontal vs. vertical orientation when exposed to flame, we decided to focus on variables of burning and heating conditions and to limit the fabric variables by studying one type of fabric at a time. Denim blue jeans were burned and heated in the first test series, and white cotton t-shirts were added in the second series.

Garments and sections of the garments were exposed to heat under the following conditions: outdoors, ignited with match flame on an open grill with good air flow; outdoors, placed into an open can and ignited; and stuffed into a closed but not airtight can and heated on an existing fire but not ignited. Swatches were also heated indoors in a muffle furnace. Regardless of burn conditions, the cotton fabric proceeded from scorching then charring in response to ignition with an outside flame, to self-sustaining flame producing charring near the flame and scorching (brown discoloration) at the char margins, to brown ash that maintained the weave structure, to white ash. The formation of white ash was accompanied by a major loss of mass; it is likely that evolved gasses are significant reaction products at this stage. The white ash at first retains a skeleton (only) of the fabric structure then disintegrates. Pieces of black charred flakes and white ash float away or blow away with air movement and wind. Different ratios of the several reaction zones (scorch, black char, brown ash and white ash) were observed in burnt residue produced under different conditions. In addition, a sticky brown viscous material was observed; the literature indicates a liquid viscous residue to be a product of burning cellulose. Observations of the residues were made using a stereobinocular microscope. The fire itself begins with open flame and continues by smoldering. The time spent in flame vs. smolder can vary considerably.

Variables in ambient conditions included temperature, wind, and humidity, but the temperature range was probably too small to be significant. Higher winds contributed to flame propagation and air movement, thus af- fected the rate of burning, but did not affect the types of residues observed. Humidity was a significant enough variable that it was varied artificially using a plant mister to compare it with burn results when other conditions were the same. When the humidity rose by 20 - 30%, ignition was slower, burn times were much longer, garments did not burn to completion, more char than ash was produced with little white ash, and residues included a greater proportion of charred fabric that retained some flexibility even after storage in drier conditions.

Variation in air flow: Tests were conducted with the good air flow of an open grill, with low to moderate winds, and with the restricted air flow of a burn can. The burn can fire residues exhibited the same stages as the fires on an open grill, but the fire itself did not flame for long, but burned with long smoldering. Nevertheless, the same sequence of burning was observed. The smoldered burn resulted in extensive areas of black charring, a quantity of layered gray ash towards the top, a small amount of brown sticky residue, and thin brittle black scale on the sides of the can. Upon sieving, the ash resolved into black charred fibers, brown ash, white ash, and mineral particles. The mineral particles were a part of the ash, and more numerous in the white ash.

White ash and brown ash were significant components of the upper part of the burn residue, and black charring was more significant deeper in the can. This differs from the residue from open fires that consisted principally of black char and white ash, with smaller amounts of brown ash. This was evaluated by sieving portions of the ash then examining samples of each

fraction microscopically (PLM). The black residue consists of charred black fibers. The brown ash

consists of individual brown non-birefringent fibrils, glass and fine minerals. The white ash consists of more glassy and highly birefringent tiny minerals. It was difficult to evaluate any differences in production of the brown sticky material under different conditions, as we did not have a good method to estimate the amount. It is possible that this material reacts further to form a hard black scale observed on the sides of the burn can and on some of the non-fabric items from the clothing such as buttons and rivets. Prior studies of thermal damage to hair suggest that length of time may be a factor in the low-temperature formation of brittle blackened residue. However, has not yet been tested on cotton fabrics. If the latter hypothesis is true, a finding of black scale may provide a clue to the burn conditions, whether air flow, heat intensity, length of burn, temperature, or some combination of the above.

The cotton garments and garment swatches that were burned in covered cans but not directly ignited, exhibited only scorching and charring in those portions of the fabric nearest the surfaces of the cans. It may be that the fires were not hot enough to permit self-ignition, and of insufficient duration to permit more extensive charring. This will be the subject of further study.

As would be expected, the burn residues from denim blue jeans also included metal buttons and rivets, and metal zipper pull-tabs and slides, but also the metal teeth from the zipper, as the fabric holding the zipper together had burnt. This argues for the sieving of ash to find not only the burnt components, but also small artifacts such as the zipper teeth. Some of the metal rivets had plastic shanks; the plastic melted and burned with decomposition. Even the 100% cotton blue jeans sometimes had cotton/poly- ester blend pockets, which burned leaving microscopic hollow black spheres adhering to blackened cotton fibers and also producing hardened areas of charred cotton fabric. A more surprising artifact from one burn included mi- croscopic pieces of what is likely to be a brown glass. The source was not determined, but it is possible that a rope trim on this garment burned leaving phytoliths (glass formed from the burning of silicate inclusions in the fibers).

This will also be the subject of further study. In addition to the physical characteristics of burnt artifacts, it was observed that in a burn test on one pair of blue jeans, the rivets popped off explosively and were propelled several feet. Accompanying char and ask fragments traveled as much as ten feet.

Further work: In addition to the topics mentioned above, heat damage to cotton fabrics in low-oxygen environments that have sufficient flow has not been studied, as well as including large quantities of other gasses such as carbon dioxide instead of oxygen is planned. This is a situation sometimes encountered in areas of fire scenes. Most of the burn products either micro- scopically or chemically have not been identified. These topics in the next phases of this study will be addressed.

Summary: Preliminary information suggests that it will be possible to correlate the alterations to fabrics damaged by heat and any resulting residues with the conditions under which the damage was produced. The most significant variables appear to be humidity, air flow and perhaps the amount of oxygen. Information from heat damage and burn residues can be useful to fire investigators in mapping the different areas of a fire and in deciding whether something burned in a flame or was exposed to radiant heat.

Thermal Damage, Textile Flammability, Forensic Science