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MELTED STEEL: How Important?

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Pick up any fire investigation text, and you will almost certainly find, somewhere, a table of melting points of metals. These melting points are provided to allow the investigator to determine how hot a particular area got by examining the condition of the metals.

Most of us expect to find melted aluminum at just about any fire scene, and the finding of melted copper is also reasonably common; although many investigators finding melted copper at "floor level," will point to one text or another which describes the fire temperature at "floor level" as no higher than 600°F and state that the presence of melted copper indicates that the floor level achieved 2,000°F and, therefore, the fire must have been intentionally set. This conclusion is certainly a stretch, based upon the evidence, especially when we consider that in many fires everything ends up at floor level eventually. The fact is...normal unaccelerated house fires can and do achieve temperatures sufficiently high to melt copper. The more advanced the fire, the more likely we are to find melted copper. It would be a rare set of circumstances which would allow us to find all of the copper intact in a black hole.

While melted aluminum and copper may be expected at most fire scenes, the presence of melted steel almost always sets off alarms in the fire investigator's mind. Melted steel, we are told, indicates that local temperatures exceeded 2,100, 2,300, 2,500, 2,700 (pick one) degrees Fahrenheit, temperatures which can only be achieved in the presence of flammable or combustible liquids.

There are two fallacies in this logic. First of all, the flame temperature of burning combustible liquids is no higher than the flame temperature of a well balanced wood fire. The function of an accelerant is not to make a fire burn *hotter*, but to make a fire burn *faster*. It does so by involving more of the ordinary combustible materials in a shorter period of time than would happen in an accidental fire. When we consider the fuel load provided by a gallon of gasoline as compared with the fuel load provided by the entire structure, the contribution of the gasoline is quite small indeed. Additionally, the gasoline is usually almost completely burned off in the first few minutes. *Are we to infer that the melting of steel occurs in this same time period?*

The theoretical flame temperature which can be achieved by hydrocarbon liquids is listed in the *Fire Protection Handbook* at between 3,500° and 4,200°F. Thus, flammable and combustible liquids are cited in an "authoritative" source as having enough energy available to actually melt steel. The temperatures in the *Handbook*, however, are for ideal flames, which are never achieved in a real fire. We have a shortage of oxygen, rather than an abundance of it, and the likely flame temperatures are below 2,000°F.

A more important fallacy relied upon by fire investigators is their belief that they can actually determine visually whether a piece of steel has melted or not. Recent studies performed in our laboratory indicate that it is not possible to tell by visual examination alone whether a piece of steel has *melted or merely oxidized*.

Four mattress springs were submitted to the laboratory for metallurgical examination. All of these mattress springs appeared to have melted, and had in fact been characterized as having melted by the investigator who examined the fire scene. Based on the presence of four melted bedsprings in the fire scene, the investigator concluded that the fire had been intentionally set.

Out of an abundance of caution, the attorney handling the claim for the insurance company decided to have the "melted" bedsprings metallurgically examined to see whether the melted condition could be scientifically verified. All four springs exhibited a decreased diameter of the base metal, and a bulbous appearance at the very end. There were no visible differences among the four apparently melted springs.

The apparently melted ends of each of the four springs were cut off and mounted in a metallurgical mounting medium, polished, etched, and examined at up to 500X. Three of the four springs exhibited a decarburized ferrite microstructure, with oxidation on the top surface. Such a microstructure is typical of steel exposed to temperatures in the range of 1,800°F.

One of the wire ends exhibited a ferrite microstructure with oxidation on the top surface and incipient melting at the grain boundaries. This particular wire end had attained temperatures of between 2,100 and 2,200°F. This wire end had, in fact, just begun to melt, which is what we would expect if there was melting farther down the wire (Figure 1).

Thus, we had four apparently identical bedsprings which had experienced temperatures which differed by up to 400 degrees. Three of the four bedsprings had not melted at all, but had merely oxidized.

When exposed to a fire, steel bedsprings will undergo four distinct changes, as the temperature increases. Unfortunately, only the first two changes are likely to be detectable by visual observation. Figure 2 shows the microstructure of a bedspring before it has been heated. The radically elongated grains are typical of spring steel. Upon exposure to elevated temperatures (up to 1,300°F), the spring will anneal and lose most of its residual tension, as a result of stress relief, as shown in Figure 3.

After exposure to temperatures over about 1,300°F, the grains of steel actually recrystallize, and the microstructure shown in Figure 4 is typical. A heavy oxidation scale will usually be present on steel which has been exposed to temperatures sufficiently high to cause recrystallization.

At even higher temperatures, decarburization (loss of carbon) of the steel occurs, and the microstructure shown in Figure 5 may be expected. This microstructure was obtained after heating at 1,800°F for two and one half hours.

Finally, when the melting point of steel is reached (somewhere between 2,200 and 2,400°F depending on the alloy), incipient melting begins in the grain boundaries. The resolidified melted material, such as that shown in Figure 1, can be identified.

Oxidation will frequently result in the formation of a stable oxide coating. In a fire, however, the rapidly changing temperatures lead to expansion and contraction of both the base metal and the oxide coating, and rapid flaking off or scaling of the oxide. Thus, more base metal is available for additional corrosion. The iron oxide scale which forms on the surface of the metal takes up more area than the surface from which it is created. Thus, we tend to have a bulbous appearance, because the outer layer has a larger surface area than the inner layer. This bulbous appearance looks very much like the balled ends of melted copper wire, and leads to the false conclusion that the steel wire has melted.

In a recent study of the accidental residential structure fires which occurred in the Oakland, California fire of October 20, 1991, fifty houses were examined. Of those, bedsprings were found decomposed in 42 of the structures. All but one of the structures had some type of steel decomposition which gave an appearance of melting. This is interesting to note in that apparently melted steel was more common in these structures than was melted copper. This only makes sense, as copper melts at a higher temperature than that necessary to cause the decomposition of steel. Thus, from the field investigator's standpoint, *a finding of melted copper may be more significant than a finding of apparently melted steel*, as the decomposition of steel giving the appearance of melting occurs at temperatures as low as 1,500°F, while copper can only melt at temperatures above 1,900°F.

Back in 1989, Tobin and Monson of the FBI Laboratory effectively debunked the myth that annealed or collapsed springs could be useful indicators in arson investigations[3]. It now appears that we have been reading too much into melted springs, as well. Not only has the importance of melted steel been overstated, but it also appears that melting has been incorrectly identified in cases where only decomposition actually existed. ***Microscopic examination of a polished cross section is the only conclusive method for identifying melted steel.*** □

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Figure 1: Field Sample of Bedspring Material Which Began to Melt in an Actual Fire. Top Surface is an Oxide Layer. Note the Presence of Resolidified Iron Sulfide in the Grain Boundaries (Arrow). Base Material Is Completely Decarburized. The Grain Size is a Function of the Rate of Cooling after Recrystallization. Quicker Cooling Results in Smaller Grains, Slower Cooling Results in Larger Grains. Nital Etch. 500X.

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Figure 2: Unheated Bedspring Material. The Metal Consists of Radically Elongated Grains of Pearlite (Dark) and Ferrite (Light) Grains. Nital Etch. 500X.

Figure 3: Bedspring Material Heated to 1,300°F for 2.5 Hours and Air Cooled. The Material Has Been Stressed Relieved, and Metallurgically Consists of Elongated Grains of Ferrite and Pearlite. Nital Etch. 500X.

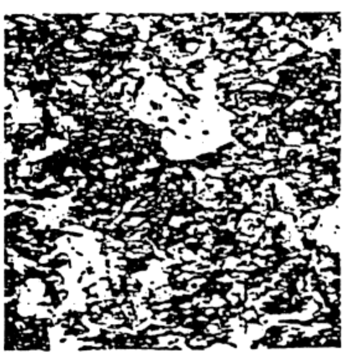

Figure 4: Bedspring Material Heated to 1,500°F for 2.5 Hours and Air Cooled. The Material Now Consists of Recrystallized Grains of Ferrite and Pearlite. Note that the Grains Are No Longer Elongated. Nital Etch. 500X.

Figure 5: Bedspring Material Heated to 1,800°F for 2.5 Hours and Air Cooled. Because of Decarburization, the Material Now Consists Entirely of Recrystallize Ferrite Grains. Nital Etch. 500X.