

Cozen O'Connor Technical Handbook:

INVESTIGATION AND ANALYSIS OF SUBROGATION CLAIMS ARISING FROM SPONTANEOUS COMBUSTION AND CHEMICALLY INDUCED FIRES

by Jon Hurwitz

I. Introduction

At one time or another, most claim professionals encounter fires caused by spontaneous combustion. Some of these losses involve well known auto-igniters, such as products containing boiled linseed oil. The February 1991 fire at One Meridian Plaza, for example, was ignited by spontaneous combustion of oily rags; this tragic loss caused over \$100 million in property damage and cost three Philadelphia firefighters their lives. Spontaneous fires, such as those involving exothermic reactors of moist organic materials, frequently are not well understood, and thus it may be more difficult than usual to prove third-party liability.

This handbook first provides a technical foundation for understanding how, when, and why spontaneous heating can occur – and under what circumstances such heating may continue and eventually result in self-ignition. It then addresses the significant recovery issues that a subrogation professional should address when confronting a loss resulting from spontaneous combustion.

As in all cases, the carrier's subrogation interests must be recognized and protected. The loss obviously should be properly investigated and thoroughly documented. Early retention of subrogation counsel is recommended to assist in this endeavor.

II. Technical Background

A. Oxidation and Combustion

The process of combustion falls within a class of chemical reactions known as *oxidation*, which is simply the chemical combination of a material with oxygen to produce relatively simple chemical compounds called *oxides*. Although oxidation reactions are almost invariably exothermic (they generate heat), many materials oxidize so slowly

that no appreciable increase in temperature occurs. This type of oxidation, which includes the rusting of iron and the yellowing of paper, is not combustion.

Even oxidation that generates a significant amount of heat is not necessarily combustion. By combining food with 200 gallons of oxygen each day, for example, humans oxidize fuel rapidly enough to maintain our body temperature at nearly 100°F (38°C); obviously, however, this does not result in combustion.

The National Fire Protection Association's (NFPA's) *Fire Protection Handbook* defines combustion as "an exothermic, self-sustaining reaction involving a solid, liquid, and/or gas-phase fuel." Because combustion requires (1) fuel, (2) heat, and (3) oxygen (or some other oxidizer), it is classically represented by the "fire triangle," in which each of the triangle's sides represents one of these three elements. If any of the sides is removed, the triangle collapses and combustion ceases. In recent years, it has been recognized that flaming combustion also requires an uninhibited chemical chain reaction, in addition to fuel, heat and oxygen. Thus, a fourth side has been added to the conceptual fire triangle, resulting in a "fire tetrahedron" or a "fire rectangle." (See *Sidebar: The Collapsible Fire Triangle*.)

Spontaneous combustion results from the accumulation of heat from oxidation reactions, and is caused by one of three mechanisms: spontaneous heating, pyrophoricity, or hypergolicity. Spontaneous heating occurs when a slow oxidation reaction generates heat more quickly than can be dissipated to its surroundings, ultimately resulting in self-ignition. Pyrophoric substances, in contrast, ignite instantly upon exposure to air. The most common pyrophoric substances are finely divided metal solids. Finally, hypergolic substances (of which pyrophoric substances comprise a subset) spontaneously combust upon exposure to *any* oxidizing agent. Because property adjusters typically encounter losses caused by only the first of these three mechanisms, this handbook will examine only spontaneous heating.

The Collapsible Fire Triangle

The fire triangle's dependence on all three of its sides is regularly exploited in fighting fires. Typical firefighting efforts target one or more of the sides in an attempt to halt combustion:

FIRST: Fuel can be removed from a fire by draining a tank of flammable liquid, digging trenches or setting backfires in the path of an approaching wildland fire, or by simply shutting off gas flow to a ruptured or leaking gas line.

SECOND: Heat can be removed, most commonly by applying water to a fire. Water has a higher *specific heat* than almost any other substance, which means that it takes

more heat to raise the temperature of water than of almost anything else. This makes water an exceedingly effective remover of heat.

THIRD: Oxygen can be removed from a fire by applying carbon dioxide or foam, shoveling dirt onto smoldering grass, or sliding a cover over a burning pan of grease.

Finally, because flaming combustion is equally dependent on the fourth side of the fire tetrahedron, a fire also can be extinguished by removing that fourth side: the chain reaction. The potassium bicarbonate or sodium bicarbonate (a.k.a. baking soda) found in common dry chemical extinguishers puts out fires effectively because it inhibits the transfer of energy between molecules, thereby breaking-up the combustion chain reaction.

B. Spontaneous Heating and Ignition of Organic Materials

Organic materials — those containing carbon as their principal constituent — are ubiquitous. As a class, organics encompass substances ranging from plant and animal matter to fabrics and plastics. Almost all organics contain varying amounts of oxygen and nitrogen, in addition to other elements. In addition, most organic materials burn readily, producing water (H_2O — which is, technically speaking, the oxide of hydrogen) and carbon dioxide (CO_2).

Organic materials are divided into two broad classes: those based on *hydrocarbon* and those based on *cellulose*. Hydrocarbons are based on completely unoxidized carbon building blocks ($-\text{CH}-$ or $-\text{CH}_2-$), whereas cellulose-based materials are derived from a partly oxidized carbon unit ($-\text{CH}(\text{OH})-$). (Although these chemical structures are somewhat beyond the technical scope of this handbook, their symbols illustrate that hydrocarbon building blocks contain oxygen while cellulose blocks do not.) Because materials based on cellulose are already partly oxidized, they consume less oxygen and produce less heat when they burn than those based on hydrocarbons. (*See Sidebar: Thornton's Rule.*)

Under proper conditions, the oxidation of some hydrocarbons results in spontaneous heating and ignition. Most commonly, this involves a combustible liquid hydrocarbon in contact with combustible materials, such as cotton rags. Some solid hydrocarbons, including coal and charcoal, also are capable of reacting directly with atmospheric oxygen to spontaneously combust.

Several factors determine whether oxidation will result in ignition:

- (1) the rate of heat generation;
- (2) the effects of ventilation;

- (3) the insulating effects of the material's immediate surroundings;
- (4) the ignition temperatures of the hydrocarbon and other combustibles, as well as of any gases liberated by the oxidation reaction;
- (5) the specific area of the hydrocarbon exposed to an oxidizer (*see Sidebar: Specific Area*); and
- (6) the amount of moisture present in the atmosphere and fibrous combustible.

If the rate of heat removal exceeds the rate of heat generation, the material will remain cool and will not ignite. Thus, if self-ignition is to occur, heat must be generated more quickly than it can be removed by conduction, convection, and radiation. (*See Sidebar: Conduction, Convection, and Radiation.*) As the temperature of the self-heating material begins to rise, however, the reaction rate often increases, which can result in a "runaway" reaction and, ultimately, ignition. In such reactions, the reaction rate generally doubles with every 18°F (10°C) increase in temperature.

Thornton's Rule

The amount of oxygen consumed is directly related to the heat produced, as is stated by *Thornton's Rule*. Named after W.M. Thornton, the individual who discovered and published the concept in 1917, this rule explains that the heat produced per unit weight of oxygen consumed by combustion differs by only about ten percent for various organic materials. Thus, while the heat of combustion varies greatly among organic materials, oxygen consumption may be used as a reasonable measure of total heat produced.

Specific Area

The *specific area* of a combustible substance, expressed in units of cm²/g, refers to the surface area, per gram of material, which is exposed to an oxidizer. Materials with high specific areas are more likely to self-ignite. Combustible liquids on fibrous materials, for example, are particularly prone to self-heating, because the fibers allow the liquid to spread out over a large surface area, creating more exposure to atmospheric oxygen.

Conduction, Convection, and Radiation

Conduction refers to the transfer of heat between two bodies through direct contact. Aluminum, steel and copper are good conductors, while fibrous materials, such as cloth and paper, are poor conductors.

Convection is the transfer of heat by the movement of air or liquid. As air (or any gas or liquid) is heated, it expands – becoming lighter – and moves upward. Cooler air takes its place at the lower levels, creating convection currents.

Radiation (a.k.a. *thermal radiation*) refers to the transfer of heat via electromagnetic energy. Radiated heat, also known as infra-red rays, is transmitted by the same mechanism as visible light, x-rays and radio waves; they differ only in the lengths of their waves. Radiated heat is a major source of fire spread to exposure properties.

C. Spontaneous Heating of Specific Materials

The most common materials responsible for causing spontaneous combustion fires are examined below.

1. *Drying oils*

Most commonly derived from plants or animals, the class of oils known as *drying oils* includes linseed (obtained from flaxseed), tung, fish, and soybean oils. (Because it dries more quickly, so-called *boiled linseed oil* is considerably more prone to spontaneous combustion than raw linseed oil. “Boiled linseed oil” refers not only to oil that has actually been boiled to concentrate the reactive fatty acids, but also, more commonly, to oil to which a drying agent has been added.)

As they dry, the fatty acids in drying oils oxidize and form a durable natural coating; for this property, drying oils have been used in paints and other finishes for centuries. Although this oxidation reaction is exothermic, its rate depends on the relative amount of oil exposed to the air. Thus, while linseed oil in a can will not self-heat to the point of ignition, it may ignite when spread across the fibers of a cloth.

If spontaneous combustion is to occur, the oil on the cloth must be exposed to sufficient air to permit rapid oxidation, and yet not be so well ventilated that the heat generated is quickly carried away by convection. As a practical example, a tightly bound bale of oily rags will not likely self-heat because it lacks sufficient oxygen to feed the reaction. Conversely, an oily rag that has been hung on a clothesline will not self-heat because the heat dissipates – primarily through convection – as quickly as it is generated.

Spontaneous heating also depends on the insulating effects of a material's immediate surroundings. For example, a rag soaked with linseed oil may self-ignite if thrown into the bottom of a wastebasket, where it is insulated by the wastebasket as well as by the crumpled rag itself. Similarly, a large pile of material may insulate the core of the pile well enough for ignition to occur. Of course, the pile must be of a material sufficiently porous to allow enough air to permeate for oxidation to occur.

2. *Cooking oils and spontaneous laundry fires*

Although common cooking oils will rarely self-ignite — even if spread onto combustibles such as cotton fabrics — they may do so when provided with an initial push: that is, when they are raised to an elevated starting temperature. This occurs most frequently when towels or other fabrics containing cooking oil residues are dried in a dryer. The high temperature created by the dryer speeds up the oxidation reaction to the point where self-heating and -ignition can occur, resulting in ignition several hours after the towels have been removed from the dryer.

Because the normal venting process of a mechanical dryer removes heat from the drum contents, spontaneous laundry fires rarely occur during the drying cycle itself. On the contrary, laundry has a greatest tendency to self-ignite when the dryer is interrupted mid-cycle, before the normal cool-down cycle has completed. It also should be noted that because bleach is an oxidizer, its residue may contribute to self-heating of laundry.

3. *Hay, straw, mulch, compost, etc.*

Although spontaneous combustion commonly occurs in piles of moist organic material, such as hay and mulch, the mechanism of this reaction is not entirely understood. In the incipient stages, heat is generated by the respiration of bacteria, molds and microorganisms. This biological process, however, can only raise the material's temperature to between 122° and 212°F (50° to 100°C), above which point the living organisms perish. Beyond this stage, scientists are uncertain about the method by which self-heating is propagated to the point of ignition.

Moisture content is a critical factor affecting self-heating of vegetable material. Spontaneous combustion may occur when moisture content ranges from about twenty to forty-five percent. Drier product cannot support the necessary biological activity, while wetter product is kept relatively cool through evaporation.

Large piles of organic material retain more heat than smaller piles, and thus are more susceptible to self-heating. In fact, fire scientists refer to the *critical radius* of a pile of a

self-heating material: below this size, spontaneous ignition cannot occur. Because coarse products, such as wood chips, permit more air flow than finer or denser products, such as mulch, coarse products can safely be stored in larger piles. Additionally, materials that degrade slowly, like dry wood chips, can be safely piled higher than those that degrade more rapidly, like wet wood chips.

Stacked hay fires generally do not occur less than ten to fourteen days after the hay is stacked, and generally require five to ten weeks. Whereas hay ignited by an external source generally shows evidence of burning from the outside in, a spontaneously occurring fire starts in the center of the stack and burns outward, often forming a sort of chimney to the exterior. Moreover, unburned hay from a stack that self-ignited is very dark in color, and may be more acidic than normal.

4. *Sawdust and wood*

Generally, wood can spontaneously ignite under two circumstances: (1) when it is present in large quantities in a finely divided state, such as sawdust or wood chips; or (2) when it is gradually charred, or *pyrolyzed*, over a period of time.

Damp sawdust or wood chips, like other moist organic materials discussed in the previous section, are susceptible to spontaneous combustion. Although solid wood is unlikely to self-heat, several attributes of finely divided solids make them a hazard. First, finely divided materials have a lower *thermal conductivity* than solids; in other words, they accumulate and retain heat more readily. Second, because particulate substances have more surface area than solids, oxidation reactions can occur more readily in the former.

Also bear in mind that friction generated by the sanding process itself typically creates warm or even hot sawdust, resulting in an increased rate of reaction. The sawdust accumulated in the collection bag of a powered floor sander, for example, is more likely to spontaneously combust than otherwise would be expected.

If solid wood is exposed to relatively low temperatures (as low as 250°F/120°C) for long enough periods of time (from weeks to years), the ensuing charring may result in the creation of a by-product known as *pyrophoric carbon*. Pyrophoric carbon can spontaneously ignite at temperatures well below the normal ignition temperature of the original wood. This species of spontaneous combustion may occur, for example, when a heater or cooking appliance has been installed too close to wood paneling. In such cases, it may be months or even years before the wood ignites.

5. *Coal and charcoal*

For centuries, it has been known that coal and charcoal are susceptible to spontaneous combustion. Various grades of coal absorb oxygen (i.e., oxidize) far more readily than others; those which oxidize more easily have, not surprisingly, a greater tendency to self-heat. Spontaneous ignition seems to occur when there is just enough airflow that the coal is able to absorb most of the atmospheric oxygen, and yet not so much airflow that it carries away the heat that is generated.

As with hay, moisture content is a critical factor in the spontaneous combustion of coal and charcoal. The higher the inherent moisture, the greater the oxidizing tendency. Finer particles of coal are more prone to self-ignite, as is freshly mined coal (upon its initial exposure to atmospheric oxygen). While massive quantities of coal are generally required before coal can spontaneously combust, activated charcoal¹ can self-heat in quantities of just several pounds. Moreover, whereas coal will not spontaneously achieve flaming combustion until days or weeks have passed, activated charcoal can ignite in as little as several hours.

Ordinary charcoal briquettes are unlikely to self-ignite unless stored in quantities exceeding fifty pounds (22.5 kg).

6. *Plastics and foam rubbers*

Various chemical products used in the manufacture of plastics and foam rubbers can undergo rapid, exothermic reactions. Residues of these chemicals can turn the end-products themselves into spontaneous combustion hazards. Materials to watch for include polyurethane foam, organic peroxides, and monomers of various plastics including styrene, methyl methacrylate, vinyl acetate, and ethylene oxide.

III. Overview of Legal Theories

Many of these complex spontaneous heating ignition sequences provide recovery opportunities for the property insurer. Potentially liable third parties in these cases generally fall into one of two categories: (1) suppliers of the self-heating product that failed to provide adequate warnings; or (2) those who used the hazardous product in a negligent manner. Although claims against the users typically provide better chances

¹ *Activated charcoal* is carbon that has been treated with oxygen to make it exceptionally porous and adsorbent. Filters containing powdered or granular activated charcoal are commonly used to remove impurities from liquids or gases.

of recovery, claims against all possible defendants should be considered and evaluated in each case.

A. Supplier Liability: Defective Warnings

A supplier of a product susceptible to self-ignition may be held liable for fire damage resulting from spontaneous combustion of that product if the supplier failed to provide adequate and conspicuous warnings and instructions to the user concerning all hazards arising from foreseeable uses of the product.² As a general rule, a damaged party can prevail against a supplier if it is established that deficient warnings or instructions rendered the product defective and *unreasonably dangerous*. Potentially liable suppliers may include distributors and retailers as well as manufacturers.

Warnings are permitted to remedy product defects only if the defects cannot be cured by a superior and cost-effective improvement in design or manufacture. Once it is determined that a warning is necessary for a product's safe use, storage, or disposal, a supplier will be held equally liable for providing an inadequate warning as for providing no warning at all. Determining the adequacy of any particular warning is fact-sensitive; consideration must be given to its form as well as its content. The warning must be provided in a form that could reasonably be expected to catch the attention of a reasonably prudent user under typical circumstances. Its content should be comprehensible by the average user and must adequately convey the nature and extent of the danger. As these guidelines are obviously highly subjective, the adequacy of a particular warning is usually a question of fact to be determined by a jury.

Although the adequacy of warnings or instructions is, in several states, defined by statute, more often it is determined by a wide range of court-defined factors. These factors typically include the following:

- (1) Conspicuity
 - (a) Size
 - (b) Shape
 - (c) Color
 - (d) Contrast
 - (e) Use of pictures or symbols
- (2) Intensity of language

² In many states, such defective warnings or instructions subject suppliers to "strict liability" (i.e., liability without fault). In practice, however, most jurisdictions require the plaintiff to prove that the defendant knew or should have known of the danger of which it failed to warn.

- (3) Location (e.g., on the product or package as opposed to only in a manual)
- (4) Language (e.g., use of Spanish on products sold in areas with high Hispanic concentration).

Notably, if too many warnings are included on a product, “warnings dilution” or “warnings clutter” can undermine the adequacy of each individual warning. In these cases, injured users may argue that the warnings were defective because they were not sufficiently simple or succinct. This same argument has been used effectively by product sellers who contend that there were too many warnings to put each on the product itself. On this basis, some courts have ruled that warnings were adequate when included only in a product’s user manual.

Finally, it should be noted that the Federal Hazardous Substances Act should not act as a bar to claims of defective warnings in spontaneous combustion cases. Although the FHSA dictates the specific form of warnings to be provided with hazardous substances, most materials subject to self-ignition are not regulated by this Act.

B. User Liability

Determining whether a user of a product susceptible to spontaneous combustion may be held liable for property damage caused by a self-ignited fire requires a traditional negligence analysis. As in any negligence case, the investigation must focus on whether the user’s conduct was reasonable under the circumstances. Generally, the user is legally at fault if he or she knew *or should have known* of the danger but failed to take adequate precautions. A painting contractor, for example, should know of the dangers of oil-soaked rags. Thus, if the contractor fails to properly dispose of these rags and the rags cause a fire, the contractor may be held responsible for the damage.

III. Conclusions and Recommendations

Spontaneous combustion losses frequently provide subrogation opportunities. Their complex technical nature, however, requires careful, analytical assessment to establish third-party liability. Artifacts must be collected, tests must be designed and performed, and evidence must be marshaled in support of the recovery claim. In all circumstances involving substantial property losses resulting from auto-ignition, subrogation counsel with the requisite legal and technical expertise should be retained promptly to coordinate the development and prosecution of the subrogation claim.

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