

Cleaning & Restoration

\$9.00

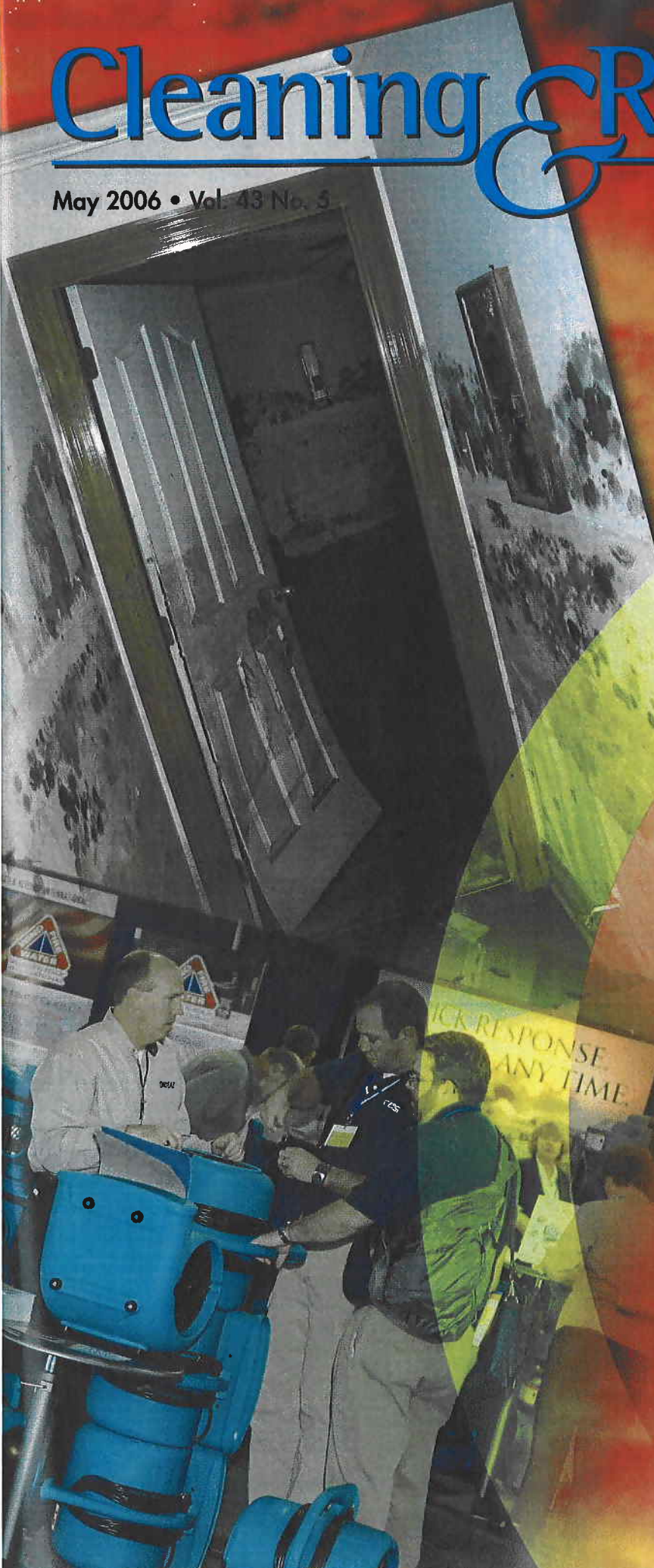
May 2006 • Vol. 43 No. 5

The Official Publication of ASCR International

Solutions to Improve Your Business

Inside:

Convention Recap
Restoration at High Temperatures
Environmental Laws and Regulations



HIGH TEMPERATURE EFFECTS ON MICRO

By Ralph E. Moon, Ph.D., CHMM, CIAQP

Editor's Note: This is the first of three articles on the use of high temperature restoration techniques.

Man has recognized the importance of heat to cook, dry and sanitize objects since the invention of fire. Within the professional restoration community, higher temperatures are an asset, increasing the ability of air to hold moisture and facilitate drying. There are several successful drying methods available to the restoration professional; a few of the more common ones are discussed in this article. Desiccant, refrigerant and convective systems offer practical solutions for the variety of drying situations encountered following water losses and catastrophic events. Though these methods differ in operation and philosophy, they share the underlying principles of lowering the relative humidity and elevating temperature. The temperatures attained by these methods vary depending on the method and the ambient conditions.

Most drying methods generate interior temperatures that range between 90 and 120 F. When supplemental heat is added to attain temperatures of 120 to 160 F or more, the objective is to reduce the level of harmful bio-organisms and reduce the potential allergens in addition to drying and desiccating. This "high temperature" procedure is intended to lessen occupant exposure to allergenic components (i.e., mold spores, mycotoxins, fungal mycelia, bacteria and pests) and odors.

Some restoration contractors who use high temperature methods refer to their allergen removal process as "pasteurization." Pasteurization is a process of heating food for the purpose of killing harmful organisms such as bacteria, viruses, protozoa, molds and yeasts (Wikipedia, 2006). The definition goes on to explain that, "Pasteurization is not intended to kill all microorganisms in the food, as compared to appertization, invented by Nicolas Francious Appert. Instead, pasteurization aims to achieve a 'log reduction' in the number of viable organisms, reducing their number so they are unlikely to cause disease." In the treatment of milk, the temperature is raised to 140 F (63 C) for 30 minutes or 161 F (72 C) for 15



RE RESTORATION: ORGANISMS—PART 1



HSA Engineers & Scientists

seconds. The various temperature regimes of living organisms, thermal death points and a description of the high temperature heating process is described in this series of articles.

High Temperature Effects on Microorganisms and Toxins

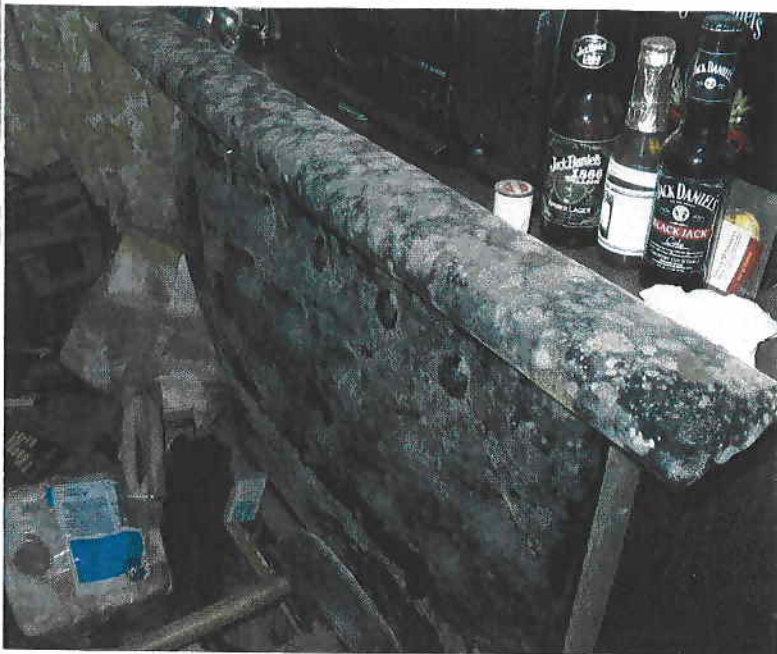
Microorganisms (bacteria) can be divided into four categories of adaptation to temperature regimes: thermophiles, mesophiles, psychrophiles and psychrotrophs (see Table 1).

Within the restoration community, we are primarily concerned with mesophilic organisms because their optimal temperatures lie within the same temperature range as the human body, our homes and workplaces. Remarkably, some organisms actually prosper at temperatures of 160 F and above. Our ability to state unequivocally that high temperatures kill particular target organisms is predicated on the ability to document sustained, uniform temperatures in the thermal kill

Table 1. Temperature ranges for prokaryotic (bacterial) microorganisms (ICMSF, 1980)

Group	Temperature °F (°C)		
	Minimum	Optimum	Maximum
Thermophiles	104-113 (40-45)	131-167 (55-75)	140-194 (60-90)
Mesophiles	41-59 (5-15)	86-113 (30-45)	95-117 (35-47)
Psychrophiles	23-41 (-5 +5)	54-59 (12-15)	59-68 (15-20)
Psychrotrophs	23-41 (-5 +5)	77-86 (25-30)	86-95 (30-35)

HSA Engineers & Scientists



HSA Engineers & Scientists

zone; this may vary depending on the relative humidity. Fungi react differently than bacteria to moist heat and dry heat; some may be sustained under heat treatment (e.g., the fungus *Aspergillus fumigatus* and the bacterium *Thermoactinomyces vulgaris*). Among the thermophilic fungi and bacteria (many of which are found indoors), some fungal spores germinate only *after* heat stimulation treatment (less than 110 F) and then grow (Yang, 2005).

Though restoration companies may not typically encounter thermophilic bacterial species, many bacterial spores, particularly *Bacillus* species (including Anthrax) are very resistant to environmental stressors, including heat, and can tolerate temperatures higher than those used in high temperature treatment. For example, Anthrax spores can be killed by boiling at 120 C (250 F) or dry heat at 159 C (318 F) for one to two hours (BioPort Corporation, 2006). The most extensive studies on the effects of heat on bacteria were conducted in the late 1800s when great scien-

Table 2. Thermal Death Points of Bacteria and Spores: An Historical Survey

Author's Note: This table provides the reader with an historical perspective on research to determine the thermal death point of microorganisms. Some genus and species names have changed over time; however, the temperature regimes are accurate.

Species	Duration & Temperature	Author
Common Bacteria		
<i>Bacillus coli</i> (<i>E. coli</i>)	10 min @ 60°C (140°F)	Loeffler, 1886
	30 min @ 65-67°C (153°F)	Escherich and Pfandler, 1903
	35 min @ 73-75°C (167°F)	De Jong and DeGraef, 1914
	15 min @ 68°C (155°F)	Shippen, 1915
	45 min @ 60°C (140°F)	Padyhe & Doyle, 1992
<i>Bacillus thermophilus</i>	5-6 hrs @ 100°C (212°F)	Rabinowitsch, 1895
<i>Bacillus typhosus</i>	10 min @ 56°C (131°F)	Sternberg, 1887
	5 min @ 60°C (140°F)	Bassenge, Mienicke & Friedel, Kolle, Kutscher, 1905
	4 min @ 63°C (146°F)	Orskov, 1926
<i>Paratyphoid bacilli</i>	20 min @ 60°C (140°F)	Krumwiede & Noble, 1921
	3 min @ 63°C (146°F)	Orskov, 1926
<i>Dysentery bacilli</i>	1 hr @ 56°C (131°F)	Thomson, 1916
	10 min @ 58-60°C (140°F)	Runge & O'Brien, 1924
<i>Brucelli organisms</i>	10 min @ 57.5°C (135°F) 5-10 min @ 65°C (149°F)	Eyre, 1912 Zwick & Wedeman, 1913
<i>Bacterium tularense</i>	10 min @ 56°C (133°F)	McCoy, 1912
<i>Hemophilus influenzae</i>	2 min @ 62°C (144°F)	Onorato, 1902
<i>Vibrio cholerae</i>	5 min @ 80°C (176°F)	Koch
	15 min @ 55°C (131°F)	Kitasato, 1889
<i>Bacillus pestis</i>	30min @ 80°C (176°F)	Kitasato, 1894
	2 min @ 60°C (140°F)	Gladin, 1898
	1 hr @ 65°C (149°F)	Kolle, 1912
<i>Staphylococci</i>	10 min @ 62°C (144°F)	Sternberg, 1887.
	35-60 min @ 75°C (167°F)	Samter, 1908
	45 min @ 60°C (140°F)	Neisser, 1921
<i>Meningococci</i>	1min @ 60°C (140°F)	Bettencourt and Franca, 1904
<i>Pneumococci</i>	15 min @ 60°C (140°F)	Wirth, 1916
	30min @ 60°C (140°F)	Baggar, 1926

tific interest was created by disease-producing organisms as noted by their original authors (see Table 2).

Heat resistance was studied and reviewed historically by several authors (Robertson, 1927; Magoon, *et. al.*, 1926) and produced conclusions that we recognize today as founding principals, such as, "The subject of heat resistance in microorganisms, in general, recognizes that young cells are more easily destroyed than old cells" (Hampil, 1932). The cause of death for bacteria can be divided into four portions: dry heat and moist heat at both low and high temperatures (Hampil, 1932.). At low temperatures, dry heat causes the formation of oxidation proteins which destroy bacteria (Paul, Birstein and Reusz, 1910). At high temperatures, two processes may occur. Protein coagulation takes place (Rubner, 1899) and scorching or carbonization of the outside which interferes with nutritive processes.

The complete destruction of bacteria by heat was first studied by Koch (Koch *et al.*, 1881). These carefully designed

experiments formed the fundamental principles of heat sterilization used today. His early experimentation showed that Anthrax required a temperature of 284 F (140 C) for three hours to kill the spores, whereas they could be killed in a few minutes when boiled. His experiments demonstrated that steam placed under pressure at an elevated temperature sterilized surfaces much more rapidly. Comparisons between the thermal tolerance of different organisms show that complex (animal, protozoa, fungi) organisms will not survive at higher temperatures as compared to simpler organisms like blue-green algae and bacteria (see Table 3).

The lethal temperature varies among microorganisms. The time required to kill depends on the number of organisms, the species, pH, duration and temperature (Todar, 2002). Laboratory research shows that the thermal death point for selected pathogenic bacteria and spores range from 131 F and 212 F (see Table 2). In a building, the ability to substantiate attaining a lethal temperature is predicated on

Species	Duration & Temperature	Author
Pathological Origin		
<i>Salmonella</i>	1 hr @ 60°C (140°F)	Feachem, 1983
<i>Shigella</i>	1hr @ 55°C (131°F)	Feachem, 1983
<i>Streptococci</i>	30 min @ 60°C (140°F)	Ayers & Johnson, 1918
	15 min @ 60°C (140°F)	Wirth, 1926
	24 hr @ 60°C (140°F)	Bagger, 1926
Non-pathogenic Mesophiles		
<i>Str. Lactis</i>	15 min @ 70°C (158°F)	Orla-Jensen, 1919
<i>B. tuberculosis</i>	6 min @ 63°C (145°F)	North and Park, 1917
Clostridium botulinum (Meyer, 1928)		
<i>C. botulinum (Type B)</i>	20min @ 80°C (176°F)	Van Ermengem, 1897
<i>Type A</i>	60 min @ 100°C (212°F)	Thom, Edmondson and Gilener, 1919
<i>Types A and B</i>	240 to 255 min @ 100°C (212°F)	Dickson and co-workers, 1922 & 1925
	300 min @ 100°C (212°F)	Tanner and McCrae, 1923
<i>Type B</i>	10 min @ 100°C (212°F)	Starin, 1926.
Anaerobic Spores Clostridium botulinum (Meyer, 1928)		
<i>Cl. welchii</i>	8 - 90 min in steam (>100°C)	Becker, 1920
<i>Cl. nouyii</i>	8 - 90 min in steam(>100°C)	Becker, 1920
<i>Vibron septique</i>	2 - 15 min in steam(>100°C)	Becker, 1920
<i>Cl. bifermentans</i>	90 - 150 min in steam (>100°C)	Becker, 1920
Other Anaerobic Spores		
<i>Bacillus thermophilus</i>	5-6 hrs @ 100 °C (212°F)	Rabinowitsch, 1895
<i>Bacillus Illidzensis</i>	4 min @ 100 °C (212°F)	Karlinski, 1895
<i>Thermophilic Cladothrix</i>	4 min @ 100 °C (212°F)	Kedzoir, 1896
<i>Cl. gelatinosum</i>	75 min @ 100 °C (212°F)	Laxa, 1898
<i>Micrococcus form</i>	10 min @ 76 °C (169°F)	Russel and Hastings, 1902
<i>Bacille</i>	Resisted hours of boiling	Tsilinsky, 1902

Sources:

Hampil, Bettylee, 1932. The Influence of Temperature on the Life Processes and Death of Bacteria, *The Quarterly Review of Biology*, Vol. 7. No. 2, pages 172-196.
Morrison, Lethe E. and Tanner, Fred W. 1924. Studies on Thermophilic Bacteria, *Botanical Gazette*, Vol. 77, No. 2, pages 171-185.

the completeness of the drying effort, performance measurements and microbial sampling. Even after the living organism is dead, fungal spores, mycelia and mycotoxins still pose an allergenic concern.

High temperature regimes do not destroy mycotoxins (Yang, 2005). The varieties of toxins produced by fungi depend on the species, growth substrate and the presence or absence of competing organisms (Burge and Ammann, 1999). The vast majority of mycotoxins have not been identified; therefore, claims of complete removal following any restoration procedure cannot be substantiated.

How Does High Temperature Work?

High temperature drying in this article is defined as 120 F and above; these conditions require specific technical instructions. Recognizing that every project must consider site-specific criteria, we can gain insight into the high temperature procedures in the specifications prepared for the Fresno Housing Authorities (SCS Engineers, 2003). The following is an abbreviated scope of work describing the technical requirements:

1. Purpose

- Drying out moist architectural components
- Killing viable biological organisms (e.g., insects, fungi and bacteria)
- Oxidizing odors

2. Site Superintendent

The contractor will employ a site superintendent as the responsible person to act as an OSHA-Competent Person who can recognize hazards and direct others. The superintendent is required to record/log all job-site work progress. The superintendent shall be fully qualified through education, training and experience to perform the work.

3. General Pre-start Inspection

The superintendent must perform an inspection of the structure before assembling heat generators or distribution equipment. The inspection will verify if the structure is safe and sound, will not be compromised when heated, and whether the structure is devoid of personal belongings. These observations will be recorded.

4. Site Set-up

The superintendent shall layout the heat generators and distribution equipment to ensure that the heat can be equally distributed within the designated area. The layout of the heating equipment shall be recorded on a drawing. All salient features of the structure shall be recorded on a drawing. The superintendent shall ensure that the heat generators are sufficiently sized to bring the structure up to

specified target temperatures and will maintain those temperatures for the specified duration.

5. Establishing Temperature Monitoring Points

To be effective, a threshold temperature must be maintained for a specified duration of time. Temperatures must be measured and recorded during the entire heat treatment process. Temperatures must be measured in real time in the air space and within various architectural components.

6. Threshold Temperature

The threshold temperature shall meet or exceed 160 F or 71 C in the majority of probes. All probes in the designated heat treatment area shall reach a minimum temperature of 155 F or 68 C. However, temperatures in the structure shall not exceed 175 F or 80 C.

7. Temperature Duration

The duration with which most temperature probes shall be maintained above the threshold temperature (160 F) is 60 minutes. The duration may vary depending on specific target organisms and/or VOCs. All probes in the designated treatment area shall be maintained at or above the threshold temperature for a minimum of 60 minutes.

8. Cool-down Period

Upon meeting temperature and duration goals, a 60-minute cool down period shall be initiated. During the cool-down period, all heat sources are turned off and the structure is to remain sealed while temperature monitoring continues.

Insight provided by high temperature drying practitioners offers practical perspectives. The difficulty of achieving lethal temperatures within the core of structural materials increases exponentially with the degree of moisture control within those materials. It is important to remember that "you can't achieve high temperatures until the wood is dry" (Vyrostek, 2006).

Moisture content can vary widely in a flooded home where some wood members may be saturated while other materials may contain sufficient water content to support microbial growth (approximately 20 percent or greater moisture). Both types of materials, saturated or elevated moisture, can be dried at temperatures less than 120 F. Proper drying, however, must consider the wide range of moisture content.

The duration of drying is critical and should be carried out slowly and uniformly over the period of time that is needed to complete the objective. As in kiln drying, differential temperatures and rapid temperature changes increase the possibility of damage as wood dries. Crawl spaces with

