A comparative study of the efficiency of dry heat, dry heat and formaldehyde, and formaldehyde in a moist atmosphere for the sterilization of used bedding.

Efficiency of Dry Heat and Formaldehyde in Sterilizing Used Bedding

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DRY HEAT alone or in combination with formaldehyde is among the methods recommended for the sterilization of bedding materials by a number of State and local government agencies. This method, however, is subject to many procedural variations.

Little information has been published on the commercial sterilization or disinfection of bedding materials by heat or by heat and formaldehyde. Sprague (*1*) used formaldehyde gas to sterilize hair and feather pillows, mattresses, and blankets. He reported that the presence of moisture and the evacuation of the sterilizing chamber prior to the introduction of formaldehyde gas enhanced the effectiveness of formaldehyde on porous materials. He also recommended the use of at least one-fourth as much formaldehyde solution as the liter capacity of the chamber. Nordgren (*2*) stated that the sterilization of porous materials by formaldehyde gas could be attained only through previous evacuation of the sterilizing chamber. Gibbons and associates (*3*) reported that hot, moist air at 275° F. for 24 to 30 hours disinfected mattresses, and that the vaporization of 80 pounds of formalin per 1,000 cubic feet of capacity was more effective for sterilizing mattresses in an evacuated chamber than in a chamber under atmospheric conditions. The American Standards Association, Inc., Subcommittee on Bedding Sterilization (*4*) reported that only surface sterilization was achieved in mattresses exposed to 230° to 270° F. for ½ to 2 hours and that the combination of dry heat and formaldehyde at atmospheric pressure did not produce complete sterilization of mattresses even at elevated temperatures for prolonged exposure times.

Other methods of sterilization which have been considered include the use of ethylene oxide or mixtures of ethylene oxide and carbon dioxide (*5*), methyl bromide (*6*), and dielectric heat (*7*).

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Methods and Materials

Escherichia coli, *Staphylococcus aureus*, *Mycobacterium phlei*, and spores of *Bacillus globigii* and *Aspergillus niger* were employed as test organisms for bedding contamination. The nonsporulating species were grown in a liquid nutrient medium at 98.6° F. for 24 hours.

B. globigii and the mold species were grown in or on a special spore medium at 98.6° F. and 86.0° F., respectively, for 4 to 5 days. Filter paper strips (Whatman No. 3, 2¾ by ½ inches) were inoculated with 0.5 ml. of a cell or spore suspension. The culture strips were dried at room temperature and viable counts of the organisms on several strips picked at random were determined by agar plate procedure. The strips were then transferred to 4 by 2½ inch paper or cloth envelopes which were inserted in or on the bedding surface for exposure tests.

The presence of viable cells in the bacterial culture strips after exposure was determined by transfer from the envelopes to tubes containing tryptose-phosphate broth and glycerol broth, and the mold spore-inoculated strips were placed in neopeptone-dextrose broth. The tubes were then incubated for 1 to 2 weeks at the optimum temperature of the test organism. Subcultures of the exposed culture strips exhibiting growth were examined microscopically for identification of the surviving organism. Inoculated but unexposed culture strips were subcultured as controls. Test results were recorded as the survival or nonsurvival of the exposed organisms in the culture tubes after subculturing. Percentage survival of the exposed organisms was not determined.

Untreated, used cotton-felt and spring mattresses and specially made cotton-felt and spring mattress sections enclosed in zippered

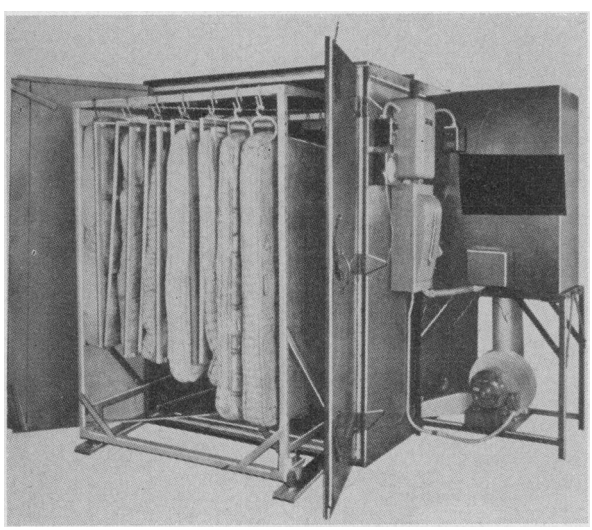


Figure 1. Electrically heated sterilizing chamber with 300 cubic feet capacity.

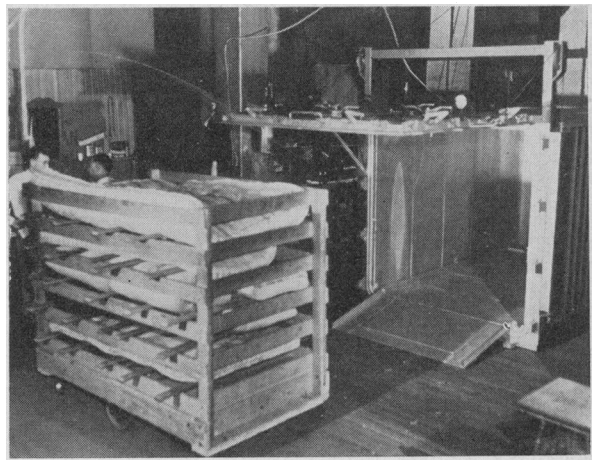


Figure 2. Nonpressure chemical sterilizing chamber with 300 cubic feet capacity.

mattress ticking were employed in the field studies. Samples of cored and uncored foam rubber (8½ by 4 by 1½ inches) wrapped in commercial mattress ticking were used in the laboratory studies. These materials were furnished by the Indiana State Board of Health, Indianapolis, Ind., and the Rubber Manufacturers Association, New York, N. Y.

Field Investigations

The major part of the field studies were conducted in commercial, nonpressure, mattress sterilizing chambers of approximately 300 cubic feet capacity (figs. 1 and 2). Air temperatures at several positions within the chambers were registered by recording thermometers. Temperatures on the surface and inside the bedding were measured by thermocouples.

Dry Heat

A number of the untreated, used mattresses and the zippered cotton-felt and spring mattress sections were placed horizontally on a mattress rack. Envelopes containing the inoculated and dried culture strips were attached to the surface of the top, middle, and bottom mattresses and inserted inside the zippered mattress sections. Additional thermocouples were also placed in these same locations to obtain temperature readings of the exposed bedding materials. The rack was transferred to a gas-heated chamber, which was equipped with a fan for circulating the air. Heat was introduced

until the desired test temperature, as recorded with a thermocouple unit, was reached inside the zippered spring mattress section. The exposure period was calculated from this point. Temperatures and exposure periods ranging from 230° F. for 2 hours to 270° F. for 1 hour were studied in these tests.

Dry Heat and Formaldehyde

In these studies, untreated, used cotton-felt and spring mattresses were suspended vertically from the mattress rack. Thermocouples and envelopes containing test culture strips were placed inside and on the mattress surfaces. The rack was then transferred to an electrically heated chamber, which was also equipped with a fan for circulating the air. Gaseous formaldehyde was generated by heating a liquid solution of 37 percent formaldehyde contained in a shallow dish on the chamber floor. Temperatures ranging from 230° F. to 250° F. for 1¼ to 2¼ hours and quantities of formaldehyde ranging from 1 pint to 1 quart per 1,000 cubic feet were tested.

To ascertain the formaldehyde concentration during the exposure periods, air samples were collected from the chamber at various intervals during the exposure period. Gas washing bottles, containing fritted glass disks and 100 ml. of 5 percent sodium bisulfite, were used to collect the chamber air from sampling ports located on one side of the chamber near the top, in the middle, and just above the chamber floor. The samples, collected at a rate of 8 liters per minute for 10 minutes, were analyzed for formaldehyde by the sulfoxylate method (*8*).

Table 1. Efficiency of dry heat in sterilizing contaminated mattresses

Test temperature and exposure time	Chamber location of culture	Survival following exposure				
		S. aureus	*E. coli*	*Myco. phlei*	*B. globigii*	*A. niger*
230° F.—2 hours	Top front	0	0	0	0	0
	Top back	0	0	0	0	0
	Bottom back	0	0	0	+	0
	Middle center	0	0	0	+	0
	Inside innerspring mattress	0	0	0	+	0
	Inside cotton-felt mattress	+	+	+	+	+
250° F.—1 hour	Top front	0	0	0	0	0
	Top back	0	0	0	0	0
	Bottom back	0	0	0	+	0
	Middle center	0	0	0	+	0
	Inside innerspring mattress	0	0	0	+	0
	Inside cotton-felt mattress	0	0	0	+	+
250° F.—2 hours	Top front	0	0	0	+	0
	Top back	0	0	0	+	0
	Bottom back	0	0	0	+	0
	Middle center	0	0	0	+	0
	Inside innerspring mattress	0	0	0	+	0
	Inside cotton-felt mattress	0	0	0	+	0
270° F.—½ hour	Top front	0	0	0	0	0
	Top back	0	0	0	0	0
	Bottom back	0	0	0	+	0
	Middle center	0	0	0	+	0
	Inside innerspring mattress	0	0	0	+	+
	Inside cotton-felt mattress	0	0	0	+	+
270° F.—1 hour	Top front	0	0	0	0	0
	Top back	0	0	0	0	0
	Bottom back	0	0	0	0	0
	Middle center	0	0	0	+	0
	Inside innerspring mattress	0	0	0	+	0
	Inside cotton-felt mattress	0	0	0	+	0

0 = No growth after subculturing and incubation for at least 1 week.
+ = Growth after subculturing and incubation for at least 1 week.

The experimental commercial chambers for the study were made available by James Miller, Fred Franke Co., Louisville, Ky. and Otis Auer, Docona Associates, Glen Ridge, N. J. Technical assistance in gas sampling and analysis and in the development of operational procedures was given by H. G. Porter and Bruce Turney, Indiana State Board of Health, Indianapolis, Ind. and John Perkins of the American Sterilizer Co., Erie, Pa.

Laboratory Investigations

Because of the increased use of foam rubber in bedding materials, laboratory tests were made to determine the physical effects of steam under pressure (248° F. at 15 pounds per square inch), dry heat (230° F.), and heat and formaldehyde in a humid atmosphere on foam rubber. Cored and uncored foam rubber samples, wrapped in mattress ticking, were employed in these tests. Unwrapped samples were also used for comparative purposes. Culture strips, containing the test organisms, were inserted in the samples to determine the bactericidal efficiency of formaldehyde and heat under moist conditions.

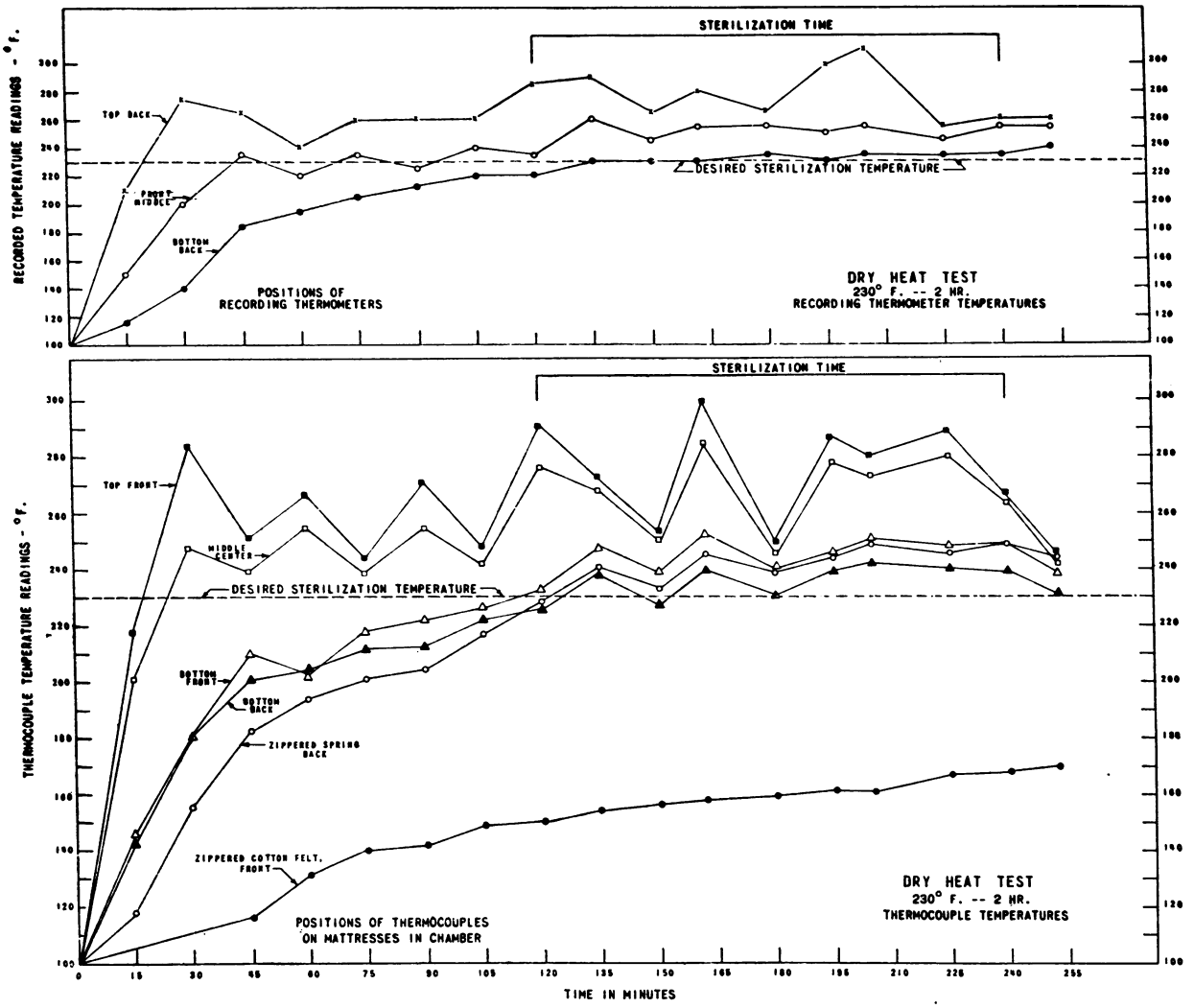
A standard laboratory hot air oven and an autoclave were employed in the heat and steam under pressure studies. The formaldehyde tests were conducted in a 1.5 cubic foot laboratory chamber in which liquid formaldehyde was vaporized from a shallow dish placed on the chamber bottom. Outlets were provided for

Table 2. Efficiency of heat and formaldehyde in sterilizing contaminated mattresses

Formalin [1]	Test temperature and exposure time	Chamber location of culture	Survival following exposure				
			S. aureus	*E. coli*	*Myco. phlei*	*B. globigii*	*A. niger*
1 pint per 1,000 cubic feet. 6 ounces per 300 cubic feet.	230° F.—1¼ hours	Top front	0	0	0	+	0
		Middle center	0	0	0	+	0
		Middle front	0	0	0	+	0
		Bottom back	0	0	0	+	+
		Inside innerspring mattress	0	0	0	+	+
		Inside innerspring mattress	0	+	+	+	+
1 pint per 1,000 cubic feet. 6 ounces per 300 cubic feet.	230° F.—2¼ hours	Top front	0	0	0	+	0
		Middle center	0	0	0	+	0
		Middle front	0	0	0	+	0
		Bottom back	0	0	0	+	0
		Inside innerspring mattress	0	+	0	+	0
		Inside innerspring mattress	0	0	0	+	+
1 quart per 1,000 cubic feet. 10 ounces per 300 cubic feet.	230° F.—2¼ hours	Top front	0	0	0	+	0
		Middle center	0	0	0	+	0
		Middle front	0	0	0	+	0
		Bottom back	0	0	0	+	0
		Inside innerspring mattress	0	0	0	+	0
		Inside innerspring mattress	+	+	+	+	0
1 pint per 1,000 cubic feet. 6 ounces per 300 cubic feet.	250° F.—1¼ hours	Top front	0	0	0	+	0
		Middle center	0	0	0	+	0
		Middle front	0	0	0	+	0
		Bottom back	+	+	0	+	0
		Inside innerspring mattress	+	0	0	+	0
		Inside innerspring mattress	+	0	0	+	0
1 quart per 1,000 cubic feet. 10 ounces per 300 cubic feet.	250° F.—1¼ hours	Top front	0	0	0	+	0
		Middle center	0	0	0	+	0
		Middle front	0	0	0	+	0
		Bottom back	0	0	0	+	0
		Inside innerspring mattress	0	+	0	+	0
		Inside innerspring mattress	+	+	+	+	0

[1] See reference 2.
0 = No growth after subculturing and incubation for at least 1 week.
+ = Growth of test culture after subculturing and incubation.

Figure 3. Representative temperatures obtained by dry heat in the sterilization of mattresses.



temperature measurements, air sampling, and internal pressure readings. The air samples, collected at 2 liters per minute for 3 minutes through fritted disk gas washing bottles containing 5 percent sodium bisulfite, were analyzed for formaldehyde by the method previously indicated.

Results

Dry Heat. Results of the commercial sterilization of bedding by dry heat are shown in table 1. Spores of *B. globigii* survived exposures of 230° F. to 270° F. for 1 to 2 hours except when the culture strips were located on the mattress surface near the top of the chamber. Nonsporulating cultures placed on mattress surfaces were destroyed under the test conditions. All cultures placed inside the cotton-felt mattress survived exposure at 230° F. for 2 hours.

Representative temperature data illustrate the elevation of temperatures at various locations in the chamber and in the mattresses (fig. 3). Temperatures of the chamber air and surface temperatures of mattresses placed near the top and in the middle of the rack increased rapidly to about 300° F. during the initial heating of the chamber. Surfaces of mattresses placed near the bottom of the rack required approxi-

mately 2 hours to reach the desired test temperatures. The desired test temperatures were never attained inside the cotton-felt mattresses exposed in the conducted tests.

No physicochemical tests were conducted to determine the effects of dry heat on exposed mattresses. Scorching was visible on the ticking of mattresses located near the top of the chamber where temperature readings ranged from 280° F. to over 300° F., which in most cases were considerably above the desired test temperatures. This indicated an uneven distribution of heat within the chamber during the exposure period.

Dry Heat and Formaldehyde. Spores of *B. globigii* survived in all the tests (table 2). The nonsporulating organisms were killed in all but one test when located on mattress surfaces but survived in some instances when placed inside spring mattresses.

Formaldehyde concentrations of the chamber air ranged from 30 to 90 mg. per cubic foot. Temperature readings during these studies were essentially the same as those shown in figure 3.

Results of Foam Rubber Tests. Discoloration, hardening and loss of elasticity and tensile strength were found in the foam rubber samples subjected to steam under pressure for a total of 3 hours or to dry heat at 230° F. for a total of 11 hours. Discoloration, brittleness, and drying of the mattress ticking were also noted.

No adverse effects were found in the foam rubber samples wrapped in mattress ticking and subjected for a total of 85 hours to formaldehyde gas (74 to 566 mg. per cubic foot) and heat (122° F. to 158° F.) at pressures of 0.56 to 4.1 pounds per square inch and at an indicated average of 50 to 90 percent relative humidity. Also no adverse effects were found in unwrapped samples of foam rubber exposed to approximately the same conditions.

Nonsporulating organisms and spores of *A. niger*, placed inside wrapped samples of foam rubber, were killed in 3 hours in the presence of about 440 mg. formaldehyde per cubic foot at 158° F. and an indicated average of 55 to 65 percent relative humidity. *B. globigii* spores survived. All test organisms were killed in 6 hours in the presence of 370 to 375 mg. formaldehyde at the same temperatures and relative humidity. The efficacy of formaldehyde in a heated, moist atmosphere currently is being studied in a gas-tight commercial, mattress sterilizing chamber of approximately 280 cubic foot capacity.

Summary and Conclusions

Results of an investigation have been presented comparing the efficiencies of dry heat, dry heat and formaldehyde, and formaldehyde in a moist atmosphere in the sterilization of used bedding materials under field and laboratory conditions using *Escherichia coli*, *Staphylococcus aureus*, *Mycobacterium phlei*, and spores of *Bacillus globigii* and *Aspergillus niger*.

Except for the organisms inside cotton-felt mattresses, dry heat at 230° F. for 2 hours in a commercial sterilizing chamber killed all nonsporulating test cultures. Spores of *B. globigii* survived all temperatures and exposure periods tested.

Considerable temperature variations were found in the bedding and in the chambers when the chambers were heated to the desired test temperatures.

The addition of formaldehyde in quantities of 1 pint to 1 quart per 1,000 cubic feet of chamber space did not enhance the sterilizing effects of dry heat alone.

Marked effects were noted in foam rubber when subjected to dry heat at 230° F. and steam under pressure (248° F. at 15 pounds per square inch). No adverse effects were observed when foam rubber was subjected to heat at 122° to 158° F. and formaldehyde in a moist atmosphere. No viable organisms were recovered from artificially contaminated foam rubber exposed to an average of 376 mg. formaldehyde per cubic foot for 6 hours at 149° to 158° F. and an indicated average of 60 to 65 percent moisture.

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technical publications

Directory of Full-Time Local Health Units, 1954

Public Health Service Publication No. 118. Revised 1954. 58 pages. 25 cents.

Revised July 1954, this directory brings up to date the listing of full-time health units serving local areas, together with the name of the health officer, or other designated administrative head, of each unit. The local units are listed by State, giving in each instance the health area jurisdiction, the post office address, and the health officer's name and his official title.

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