Design of Thermal Destruction Apparatus

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SEVERAL methods have been described and employed to determine the heat resistance of bacterial spores. These methods include: *(a)* the thermal death time tube method (2)*, *(b)* the thermal death time can method (1), *(c)* the rate of destruction method (9), *(d)* the thermoresistometer method (8), and *(e)* the miniature retort method (7). The thermoresistometer and miniature retort methods have been designed to increase the accuracy of studies of the resistance of bacterial spores in the temperature range of 250 to 270 F.

In the course of investigations at this laboratory the need and desirability of an apparatus such as described by Stumbo (8) became apparent. A survey of the problem indicated that the new apparatus should permit studies at temperatures as high as 300 F and at times as short as 0.0075 min. Stumbo (8) used open metal cups as containers for the samples under study. In this method of exposure the top surface of the sample and the bottom surface of the cup are in contact with the heating medium, which is saturated steam. Pflug (4) demonstrated that by sufficient reduction in the depth of a uniform layer of sample in an open metal cup the heating and cooling lag factors may be reduced to a point where they are not significant.

The basic requirement of the apparatus was that it be able to move six open metal cups rapidly into and out of a chamber that contained steam under a maximum pressure of 67.01 psia, corresponding to 300 F. Secondary considerations were *(a)* that the temperature control should be accurate and automatic, *(b)* that the timing and movement of all parts that may influence reproducibility should be done mechanically to eliminate any human error or variation, and *(c)* that it must be possible to control, vary, and measure the length of exposure. The design used in the final construction was essentially that presented by Pflug (3). Samples to be tested would be placed in small open metal cups, 0.433 in outside diameter by 0.333 in deep, punched out of 0.008-in-thick tinplate. Horizontal pistons with special compartments for the cups would convey them into the steam chamber for exposure. The cups would then be withdrawn and recovered for final testing. The piston would move in a cylinder, and compression rings would effect a seal. A pneumatic cylinder would operate the six pistons which move the cup from the loading position into the exposure position and, after exposure, return the cup and sample to the initial point for unloading into subculture or recovery tubes of media. The pneumatic cylinder would be controlled through a four-way solenoid valve which is in turn controlled by automatic timers. The temperature in the steam chamber would be controlled indirectly by a pressure controller maintaining a constant steam pressure. A vertical cross section of the machine is illustrated in Fig. 1.

CONSTRUCTION

The steam chamber consisted of a 36-in length of standard 8-in pipe with the ends closed by flanges. Its volume of approximately one cubic foot was considered the minimum for obtaining the desired temperature control. A slot was cut in the front of the pipe and a 2½ x 1¼ x 12½-in cold-rolled steel bar welded in the opening. This reinforcing bar serves as a mounting bracket for the antechamber and also to reinforce the pipe where the section is reduced for inserting the cylinders. Diametrically opposite the reinforcing bar a hole was bored in the pipe, and a 2½-in-diameter by 3-in long steel bar was welded in place for the pneumatic cylinder-rod stuffing box. The stuffing box was bored in place to obtain true alignment with the cylinders. The antechamber was made from a solid 3¼ x 4½-in steel billet. The sample-carrying pistons were 1 in in diameter, and the cylinder sleeves in which the pistons moved were 1¼ in outside diameter. Both the piston and the cylinder sleeves were made from bearing bronze. The cylinder sleeves were mounted in the antechamber and extended 4 in into the exposure chamber; the outside end of the cylinders was

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*Number in parentheses refer to the appended references.

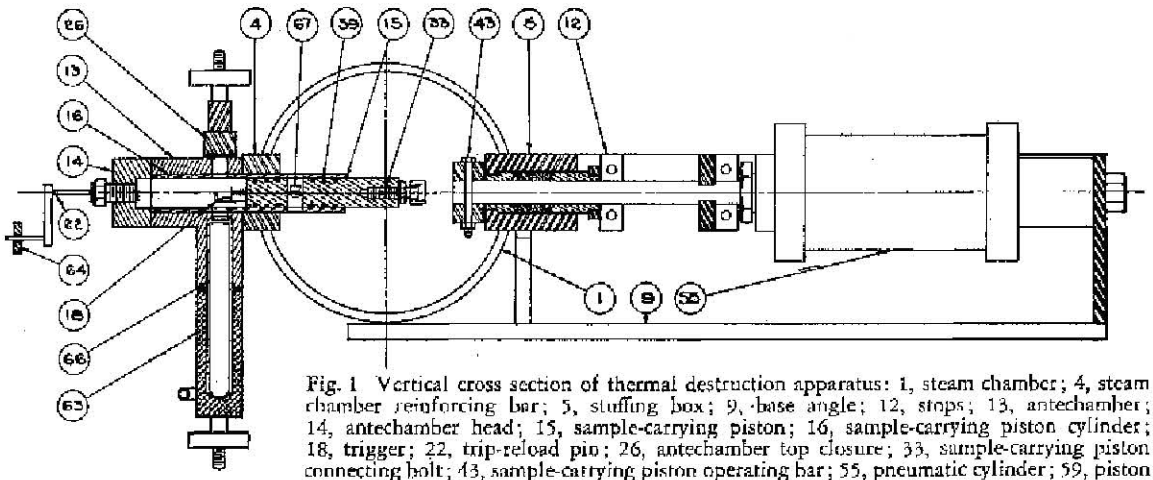

Fig. 1 Vertical cross section of thermal destruction apparatus: 1, steam chamber; 4, steam chamber reinforcing bar; 5, stuffing box; 9, base angle; 12, stops; 13, antechamber; 14, antechamber head; 15, sample-carrying piston; 16, sample-carrying piston cylinder; 18, trigger; 22, trip-reload pin; 26, antechamber top closure; 33, sample-carrying piston connecting bolt; 43, sample-carrying piston operating bar; 55, pneumatic cylinder; 59, piston rings; 63, subculture tube holder; 64, load trip bar; 66, subculture tube; 67, sample cup

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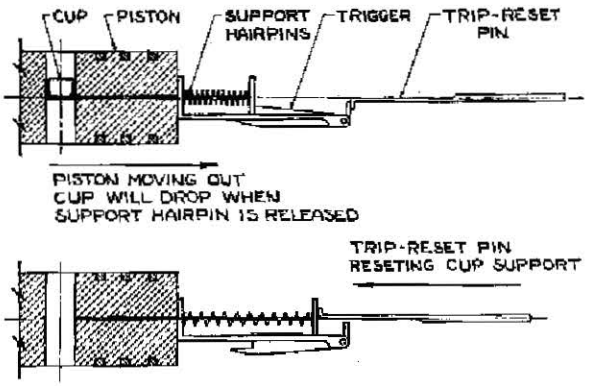

Fig. 2 Operation of trip and reset mechanism

closed by a bar acting as a cylinder head. The cylinder head and antechamber were fastened to the exposure chamber reinforcing bar with capscrews.

The sample-carrying pistons are operated by the pneumatic cylinder, which is in line on the opposite side of the steam chambers. Three compression rings are located on each side of the sample port. The position of the rings and of the relative ports are designed so that two rings carry the steam pressure at all times. The six pistons are connected to a common operating bar, which is actuated by the pneumatic cylinder. This arrangement required only one stuffing box but presented an alignment problem. To eliminate the necessity for perfect alignment, a special connecting unit was designed to transmit tensile and compressive forces and at the same time to permit a small amount of angular movement.

The sample-cup-support hairpins plus the springs and trigger mechanism are of prime importance in this design. The method of resetting and tripping the hairpins is shown in Fig. 2. It was desirable that the samples be automatically dropped into the subculture or recovery tubes upon withdrawal from the steam chamber. To accomplish this end, the trip-reset-pin unit was made adjustable; it is screwed in and locked so that the tip of the trip-pin will just meet the trigger when the pistons are withdrawn. The trip-reset pin cannot be turned from reset to trip position except when the samples are in the steam chamber. The trip-reset pin can be turned from trip to reset position when the pistons are in the load position.

The loading and unloading chamber was made pressuretight by means of the top closure bar and recovery tube support, both illustrated in Fig. 1. A pressuretight chamber is necessary for sterilization when working with microorganisms and so that compressed air can surround the samples to prevent ebullition when they are withdrawn. The apparatus was equipped with a glass wool bacteriological air filter and piping necessary to conduct the sterile air into the recovery-tube support block. A steam line was run from the steam main to the antechamber; to sterilize the apparatus, the inlet port

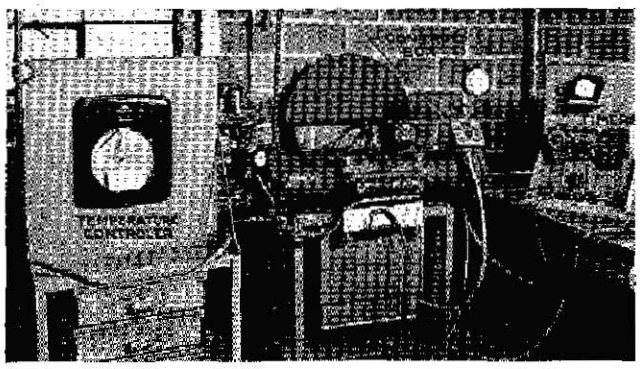

Fig. 3 Operating arrangement of the thermal destruction apparatus

of the air filter and the line to the steam main were opened. Steam then flowed into the antechamber and out through the air filter. When steam flowed freely through the system, the air filter valve was partially closed to give a steam pressure corresponding to 300 F for five minutes to effect complete sterilization.

OPERATION AND CONTROL

The temperature-control system consists of a Foxboro† Model 40 air-operated proportional-type controller having reset rate action (Fig. 3) used in conjunction with a ⅜-in air-operated needle valve. The controller maintains a constant steam pressure corresponding to the saturation pressure of the desired temperature. The steam pressure is indicated by a pressure gage. The temperature is checked, using a mercury-in-glass thermometer, smallest division 0.25 F., inserted in a 6-in-deep copper well. When the controller is properly adjusted, the temperature is maintained to within plus or minus 0.10 F.

Since this apparatus is designed to measure the time-temperature effect of different products, it is important to control and measure the time the samples are exposed to the respective temperatures. The control box in Fig. 3 is used to operate the apparatus. It contains the switches and push button illustrated in the simplified wiring diagram (Fig. 4). The control system was designed so that either an automatically timed operation or a manual operation could be employed. For simplicity, only one cycle timer‡ is illustrated in

†Manufactured by the Foxboro Co., Foxboro, Mass.
‡Manufactured by Eagle Signal Corp., Moline, Ill.

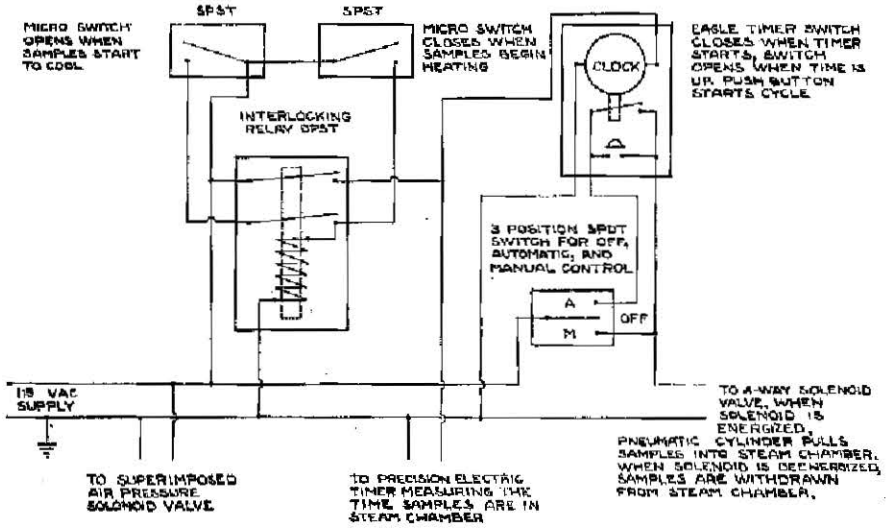

Fig. 4 Wiring diagram of electrical control system

the wiring diagram. However, in order that comparable accuracy can be had at short as well as longer time intervals, three cycle timers with ranges of 0 to 20 sec, 0 to 120 sec and 0 to 20 min are employed. When an automatically timed cycle is used, the samples are loaded into the machine, the cover closed, and the push button pressed to actuate the mechanism to pull the samples into the steam chamber. The cycle timer starts when the samples are exposed to the steam and activates the solenoid to withdraw the samples about 0.005 min before the indicated exposure time is up. It requires 0.005 min to complete the withdrawing cycle. About 0.010 min before exposure is complete, the solenoid valve controlling the sterile compressed air is opened to insure transfer of the samples to the recovery tubes without loss from ebullition. As the samples come out, they drop into the recovery tubes where they are cooled by quenching. The actual length of exposure is measured by a Precision§ timer, smallest division 0.001 min, with an accuracy of ± 0.0002 min. The timer is operated by microswitches and an interlocking relay, illustrated in Fig. 4. The microswitches are operated by a lever from the pneumatic cylinder rod.

SUMMARY

The design, construction, and operation of an apparatus made specifically for studying the time-temperature effects on bacterial spores and chemical compounds have been discussed. This machine has been in use for two years during which time more than 30,000 tests have been run. The results of some of the work have been reported by Pflug and Esselen (5) and (6). The apparatus has a production rate of more than 170 samples per hour, when the exposure times are less than 0.30 min.

§Manufactured by Standard Electric Time Co., Springfield, Mass.

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