LOAD TESTING OF AUTOCLAVES

Guy Snelling
InterCal
intercal@acenet.co.za

Abstract

Although calibration of autoclaves is usually performed with the chamber empty in order to validate the specification and performance of the autoclave itself, these results can only be used as a baseline for the intended use of the autoclave. The results thus obtained give no information as to the performance of the autoclave when loaded, and also give no indication of how a typical load will react during a sterilisation cycle.

This paper endeavors to show firstly how load testing of an autoclave may be performed, and then to give typical results for various loads in various types and sizes of autoclaves. It is hoped that this information will prove useful to laboratory staff when determining sterilisation cycle times for their particular application.

Introduction

Typically autoclaves are used to kill organisms on the surface of objects and in liquids. As will be seen, the gas temperature inside the autoclave reaches sterilisation temperature (usually 121 °C) fairly quickly and this is controlled by the autoclave control system (either by a pressure sensor or by a temperature controller). Organisms on the surface of objects are therefore exposed to the sterilisation temperature and are killed as required. However, liquids have a high thermal mass and will take much longer to reach the sterilisation temperature. Organisms **inside** these liquids may therefore never be exposed to the sterilisation temperature before the sterilisation cycle is complete. Sterilisation cycle times may thus need to be lengthened to accommodate such liquids. This paper shows typical examples of containers of liquids being exposed to certain sterilisation times and the temperatures achieved inside the liquids.

Procedure

In terms of current autoclave and steriliser testing requirements, temperature inside the chamber must be measured using 10 thermocouple probes, and also the pressure of the chamber must be monitored.

This procedure was followed during all the tests mentioned in this paper. The thermocouple and pressure values were read and recorded using a Fluke 2635 “Hydra Data-bucket” fitted with 10 thermocouple probes and a pressure transmitter.

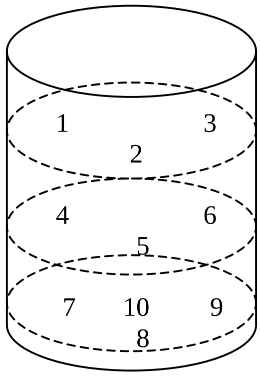
Autoclave Setup

Thermocouple positions

Thermocouple probe positioning varies depending on the size and shape of the autoclave chamber, although some standard has been reached by this author for various type of autoclaves when testing an empty chamber.

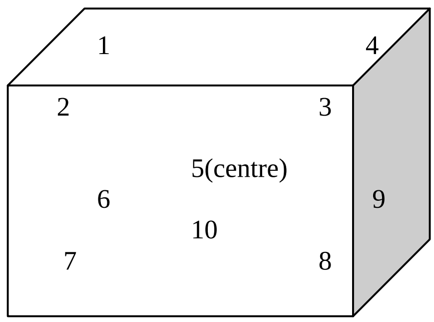
Vertical autoclaves

In these chambers the probes are positioned in groups of three around the circumference of the chamber at three different heights, with the tenth probe being positioned at the very bottom of the chamber near the drain.



Horizontal autoclaves

The probes are positioned in two levels of four probes at each of the four corners of the chamber, with the ninth probe being placed in the centre and the tenth again being placed in or near the drain.



Pressure sensor

Since the pressure in a closed system is equal at all points, it is only necessary to introduce a pressure sensor into the chamber at a single point, usually the same point through which the thermocouple probes are fitted.

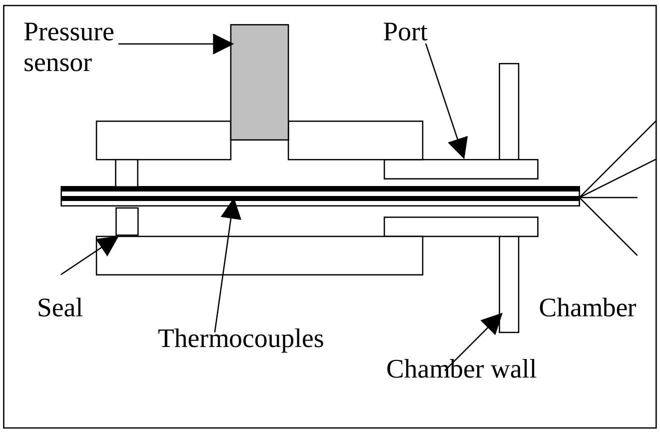


Diagram showing typical installation of thermocouples and pressure sensor in chamber wall

Loads

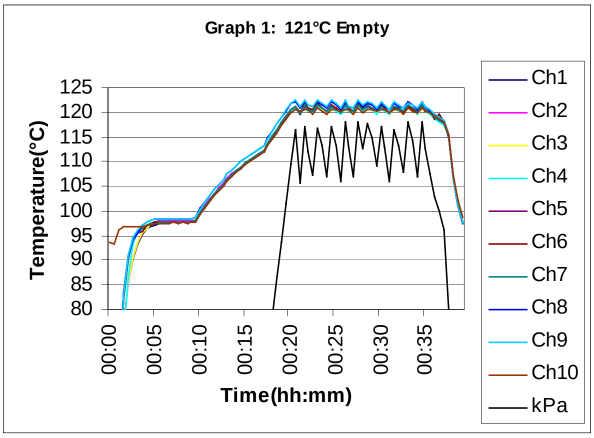
Typical loads encountered by this author include empty glass and plastic vessels and utensils, and liquids contained in vessels from 9 ml to 20 l.

Results

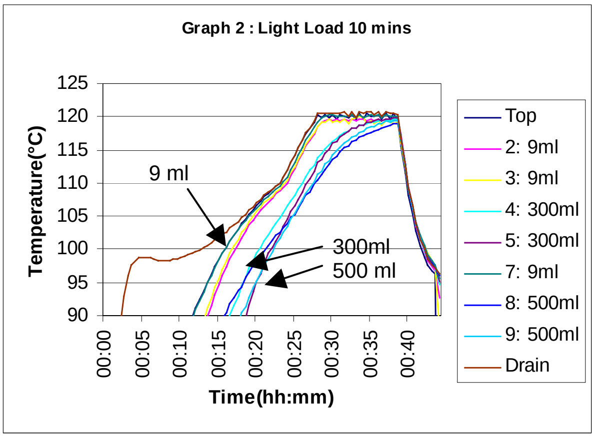
The following results were obtained from a vertical autoclave containing loads in two baskets. The loads tested are shown in the following table:

Load	Basket	Description
Light	Top	Rack of 48 test tubes each containing 9ml of water. Two 500ml bottles each containing 300 ml water.
	Bottom	Rack of 48 test tubes each containing 9ml of water. Two 1000ml bottles each containing 500 ml water.
Medium	Top	Two 1000ml bottles each containing 500 ml water. Four 500ml bottles each containing 300 ml water.
	Bottom	Four 1000ml bottles each containing 500 ml water.
Full	Top	Three 1000ml bottles each containing 500 ml water. Nine 500ml bottles each containing 300 ml water.
	Bottom	One 2000ml bottle containing 1000 ml water. Eight 1000ml bottles each containing 500 ml water.

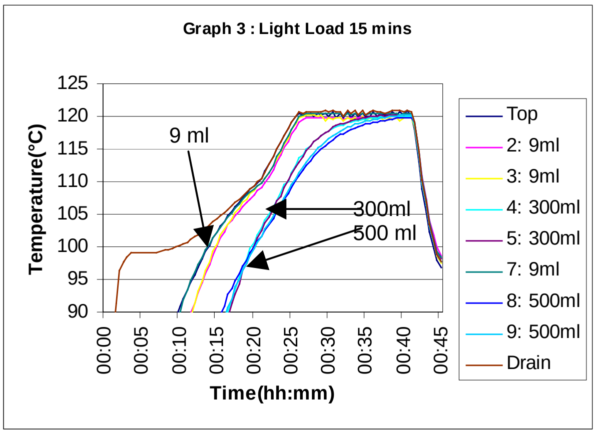
Table 1
Loads used in Graphs 1 to 5



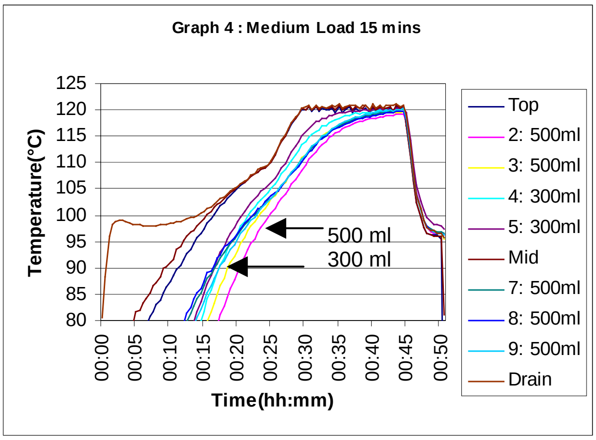
Graph1: Here the control cycle of the empty autoclave can be seen. The chamber temperature varies between 119 and 123 °C with a rise time from the air purge point of about 10 minutes. The pressure results were omitted from the following graphs, for clarity.



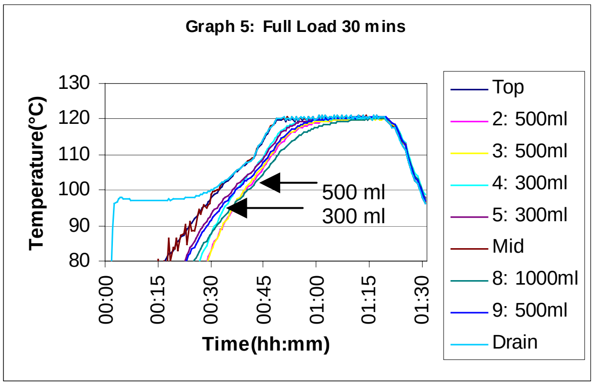
Graph 2: Here the temperature of the liquid in the 9 ml bottles followed the chamber temperature with a lag time of just 3 minutes, whilst a long lag time is apparent for the 300 and 500 ml volumes. In fact they did not reach the sterilisation temperature before the end of the cycle.



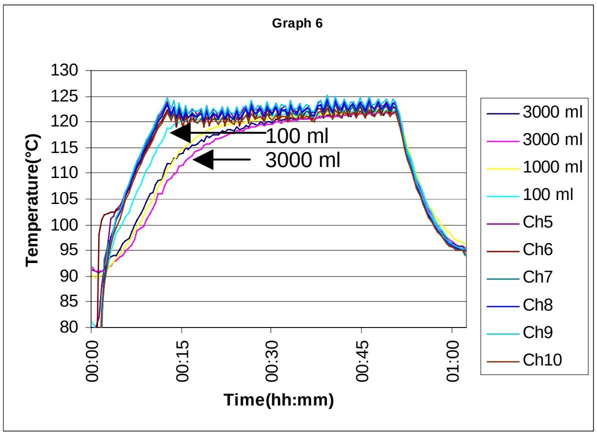
Graph 3: Here the cycle time was lengthened and lag time was found to be 12 minutes for the 300 ml volume and 16 minutes for the 500 ml volumes.



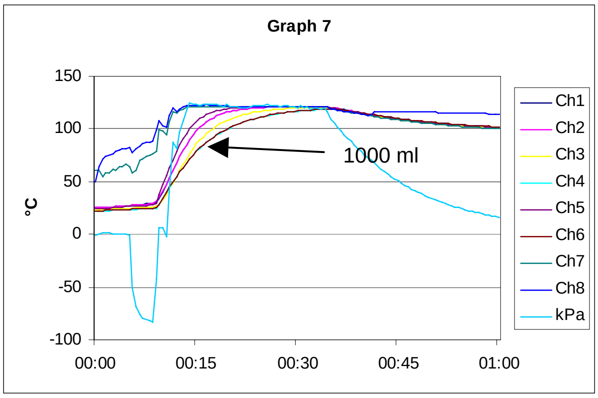
Graph 4: The medium load was then run for 15 minutes and the 500 ml loads again only reached sterilisation temperature at the end of the cycle.



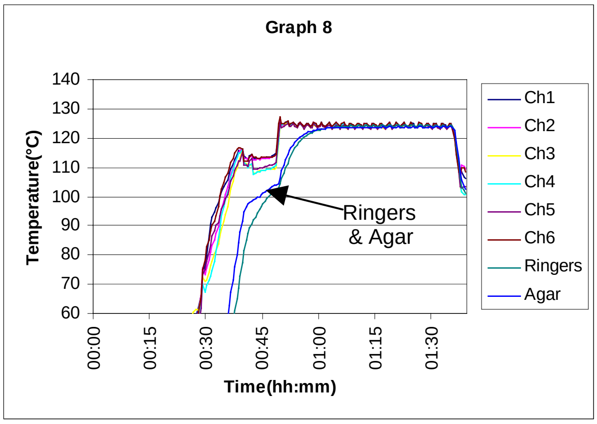
Graph 5: Based on the previous data, the full load was run for 30 minutes. The 500 ml loads had a lag time of 16 minutes and the 1000 ml load, 21 minutes.



Graph 6: During the calibration of a different vertical autoclave similar results were obtained for 1000 ml. Here a test was performed using 3000 ml and the lag time was found to be 28 minutes.



Graph 7: In this case, a microprocessor controlled horizontal autoclave of much larger volume was used. Again a lag time of 20 minutes for 1000 ml was measured.



Graph 8: In this case, another horizontal chamber but with pressure control, the sterilisation temperature was set to about 124 °C. The 500 ml ringers and 500 ml agar solutions both reached 121 °C 10 minutes after the chamber but took another 10 minutes to reach the final chamber temperature.

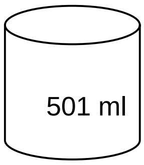
The typical lag times for certain loads were thus found to be as follows:

Volume(ml)	Lag time(minutes)
9	3
300	12
500	16
1000	21
3000	28

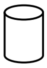
Table 2
Lag times for various volumes

Conclusions

Obviously the temperature rise time of the liquid is proportional to the surface area that is exposed to the steam temperature. For example assuming that we wish to sterilise 500 ml of liquid. In a flask of 78 mm diameter and 105 mm height we would have a surface area of 35269 mm^2. The same volume in 50 x 10 ml flasks of 26 mm diameter and 19 mm height would have a total surface area of 2612 x 50 = 130624 mm^2 – an improvement of a factor of 3.7 !.



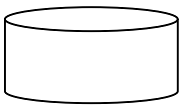
78 mm D x 105 mm H = 501 ml
= 35269 mm^2 surface area



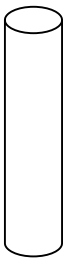
10ml X 50 = 500 ml

26 mm D x 19 mm H = 10 ml
x 50 = 130624 mm^2 surface area

Of course the shape of a container will also contribute to available surface area, since a tall, narrow container will present more of a total surface area than a shallow, wide one.



105 mm D x 58 mm H = 502 ml
= 36432 mm^2 surface area



34 mm D x 550 mm H = 499 ml
= 60533 mm^2 surface area

Recommendations

When setting up protocols for sterilising liquids in an autoclave, consideration must be given not only to the programmed time, but also to the volume and shape of the containers. Allowance should be given for the typical lag times shown in Table 2. In order to shorten total cycle times, and to ensure that all the liquid reaches the sterilisation temperature, it is recommended that many small volume containers be used, rather than a few large ones.

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