THE FACTORS INFLUENCING STERILISATION BY LOW PRESSURE STEAM

PART II. THE INFLUENCE OF WATER CONTENT OF COTTON GOWNS ON EQUILIBRIUM TIMES

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Received June 1, 1958

Variations in the times to reach steam temperature by surgeons' gowns within a steam steriliser with air elimination by downward displacement and evacuation have been examined. Using surgeons' gowns equilibrated with normal atmospheric conditions, about 60 to 70 per cent relative humidity, the times taken for the gowns to attain steam temperature were variable, whichever method of air removal was employed. Gowns dried at 50° rapidly attained steam temperature and then superheated to a considerable degree. The superheat was maintained for long periods.

WE have described elsewhere[1] the design of a low pressure steam steriliser and its associated recording instruments. The same experiment uncovered the unsuitable nature of existing steam traps and led to the design of a satisfactory modified trap[1].

Using the steriliser and instrumentation outlined in the foregoing paper[1], experiments were now made to examine further the conditions within the chamber, only this time the chamber was filled.

EXPERIMENTAL

With the steam trap used in Experiment No. 3[1] a dressing drum 13 in. in diameter and 9 in. deep was packed with five folded surgeons' gowns and positioned on its edge centrally in the chamber with the folds in the gowns in the vertical plane. One thermocouple was positioned at the centre of the gowns and a second 1 in. from the outer edge. Others were in the chamber drain and steam supply. A fairly rapid attainment of temperature was recorded by the outer thermocouple but the inner thermocouple lagged considerably.

When the steam trap was replaced by the new modified steam trap used in Experiment No. 16[1] and the experiment repeated the time to attain steam temperature was much reduced, but variations occurred in the times to reach steam temperature and in the case of the longer periods slight superheat was shown by the thermocouples within the gown. The same five gowns were used for each experiment being dried successive in a hot air oven on each occasion and allowed to equilibrate in the atmosphere at a 60 to 70 per cent relative humidity to within 2 per cent of a standard weight. Examples of these variations which are too large to be accounted for by experimental error are as follows.

Time to reach Steam Temperature in minutes

Drain	*Centre of Gowns*	*Edge of Gowns*
7	23	4·5
7·5	35	7·5
4·5	24	29
4·5	More than 60	More than 60

The experiment was now repeated with the gowns dried for 24 hours in a hot air oven at 50° C., during which time they lost about 5 per cent in weight. They were then submitted to the sterilising cycle (Fig. 1). The dressings attained steam temperature almost as rapidly as an empty chamber and superheated to 6° C. (11° F.) above steam temperature. The experiment was repeated and continued until equilibrium was attained (Fig. 3). It took 59 hours for the centre of the gowns to fall to steam temperature.

Using the same arrangement of steam inlet, condensate outlet and steam trap, a vacuum pump was now attached to the lower union at the back end of the steriliser and a mercury manometer to the central one.

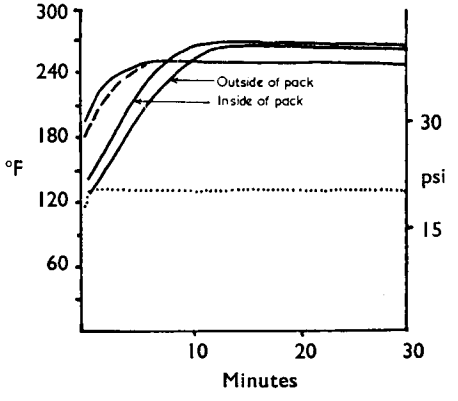

FIG. 1. Showing superheating of interior of gowns.
——— Steam pressure
– – – Drain temperature
..... Pressure

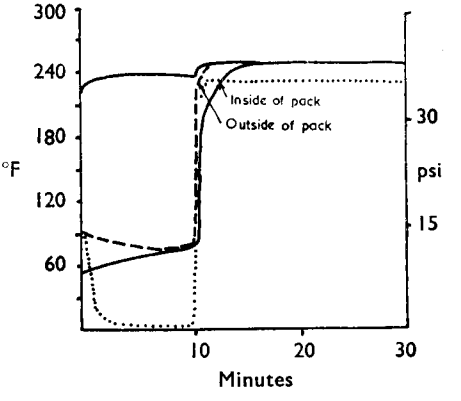

FIG. 2. Temperature of gowns attained after initial evacuation of the sterilizer.

The required degree of vacuum was pumped after first closing valve X, Figure 1 of the previous paper, on the condensate outlet, steam turned on and this valve opened as soon as the pressure within the chamber just exceeded atmospheric pressure. Evacuating to 20 in. of mercury vacuum experiments were carried out using both the unmodified and the modified steam traps and with the dressing drums filled with equilibrated gowns. The modified steam trap again behaved a little better, and steam temperature was attained in about 20 minutes. The type of trace obtained is illustrated in Figure 2. No superheating occurred.

Experiments were then made with the chamber evacuated to 40 mm. of mercury, the highest vacuum which could be achieved with a heated jacket. Steam temperature was attained in about 15 minutes and there was no superheating. The type of trace is illustrated in Figure 2.

Using dried gowns the chamber could be evacuated to 20 mm. of mercury and these conditions were used for further experiments. Steam temperature was attained in 3 minutes and the centre of the gowns superheated to 8 to 12° C. (17 to 21° F.) above steam temperature.

Discussion

The conditions within the steriliser can be modified both by external influences, and also by the physical state of the material undergoing sterilisation.

The cotton fabric used in our experiments readily attains steam temperature when air is eliminated by downward displacement if the steam trap is efficient, but the drain temperature is not found to be a reliable indication of the temperature of the steriliser contents.

In addition, superheating occurred only when the gowns had been dried to 50° C. and the period this superheat is maintained is protracted.

Rapid attainment of steam temperature and superheating which occurred only with gowns that had been dried in a hot air oven leads to a consideration of the degree of hydration of the fabric prior to autoclaving. This single factor appears to have an important effect on sterilising times and conditions.

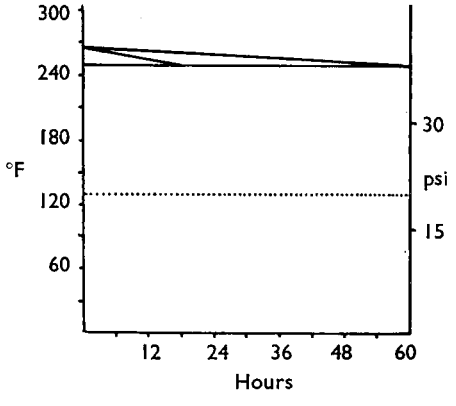

FIG. 3. Period of maintenance of superheat.

Two possible explanations suggest themselves. The first is the great difference between the thermal conductivity of dry air and air containing water vapour, and the second is that heat is evolved when the cellulose fibres re-hydrate after drying. Steam condensing on the cotton, would tend to be adsorbed to the cotton fibres, liberating its heat of hydration and thus raising the temperature locally, so causing superheating. Since cotton or cellulosic materials also possess high thermal insulation values, the conditions would be unlikely to reach equilibrium quickly with the steam external to the dressings.

This theory is supported by approximate calculations, which show that the degree of superheat in practise is close to the figure estimated by reference to tables[2] giving the heats of hydration of cellulose. Knox and Penikett[3] have reported a significant decrease in the time required to reach 115° C. (240° F.) if the vacuum obtained is below 20 mm. With the particular apparatus available and an efficient vacuum pump capable of producing a vacuum of 0·1 mm. of mercury on a closed circuit, with a capacity of 450 l. per minute, we have been unable to reduce the pressure within the chamber below 20 mm. of mercury when the jacket was heated, although the vacuum in the pipeline attached to the pump was below 5 mm. of mercury. Even under these conditions there was no great increase in the rate of attainment of sterilising temperature within the steriliser contents compared with the same chamber emptied of air by downward displacement.

Since the work reported in the paper has raised a number of contentious points it is clear that further work must be done before any tests are

designed using bacterial spores to ascertain whether ideal theoretical conditions do in fact bring about sterility.

REFERENCES

1. Barson, Peacock, Robins and Wilkinson, *J. Pharm. Pharmacol.*, 1958, **10**, *47 T.*
2. International Critical Tables, **5**, 143.
3. Knox and Penikett, *Brit. med. J.*, 1958, **1**, 680.

DISCUSSION

The papers were presented by MR. G. R. WILKINSON.

MR. D. W. HUDSON (Hove). The question of time and temperature should be considered in parallel with the destructive effect upon the fabric itself.

DR. R. M. SAVAGE (Barnet). Drums were being discarded in favour of fabric packs. The rate at which steam penetrated ordinary paper was surprising and a paper wrapped article would sterilise almost as quickly as an unwrapped one. He did not agree that there was no information about traps in the literature. Conrad in Berlin was working on the subject in 1924. Dressings containing 8 per cent or more of water might be sterilised by dry-heating, but if below this critical value, water must be added.

MR. G. SYKES (Nottingham). Sterilisers sometimes needed modification and were often mishandled. To be effective, evacuation must be to less than 20 mm. Hg. He has been told that Spirax traps were satisfactory.

MR. W. T. WING (Newcastle on Tyne). A new type of steriliser from Germany untilises a vacuum pump; this allows almost complete removal of air and penetration of steam.

MR. T. D. WHITTET (London). Sterilisation procedures were unsatisfactory in many hospitals. Some errors could be avoided by the use of temperature recording apparatus. In Sweden a nylon film was being used satisfactorily as a dressings container.

MR. WILKINSON replied. To obtain satisfactory sterilisation, the dressings must be in saturated steam, but pockets of superheat might exist where sterilisation may not take place. A balance must be achieved between sterilisation and destruction of the dressings. Drums were more easily handled than fabric packs; paper wrapping was effective unless it was damaged. He had referred specifically to the literature dealing with steam traps for sterilisers. A modified type of Spirax trap was successful. There was much evidence that removal of air was advantageous but it was difficult to achieve this without drying the dressing. He was investigating a prototype steriliser with a mechanical pump. Time and temperature were both important but what parameter was to be used? The customary thermometer at the top of the chamber or in the chamber drain did not necessarily give the true temperature at the centre of the dressings.