Present Sterilizing Practice in Six Hospitals

The Nuffield Provincial Hospitals Trust
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ACKNOWLEDGEMENTS

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FOREWORD

THIS report is a summary of the detailed findings of the Trust's operational research team who have investigated over the past 14 months the sterilizing arrangements in six different hospitals. The work undertaken in these hospitals represents the first phase of the Trust's project on the organization of central sterile supply departments.

Originally it was intended to include the report in the completed one on central sterile supply departments which will be published later. It would have formed the introduction to show present day sterilizing techniques and would have been compared with the potentialities of central sterile supply over these procedures.

The results of the investigation of the operational research team have, however, been so revealing, especially when considered in the light of the present high incidence of hospital infection, that the advisory panel have recommended to the trustees of the Nuffield Provincial Hospitals Trust that they should publish this report for the information of hospital authorities at once.

The report shows that the standards of sterilizing practice in the six hospitals investigated are open to criticism. It is reasonable to assume that standards throughout hospitals in England may be similar. Low standards may be associated with the abnormal conditions that existed in hospitals during World War II, together with the undue reliance placed on the use of antibiotics for the last 15 years. The imperfections of sterilizing technique may be a major contributing factor to the present high incidence of infection in hospitals.

The present high incidence of hospital infection is a matter of great concern. About 100 years ago Lister was faced with a similar problem. Apart from his epic work on antisepsis he also insisted on aseptic procedures in his wards and theatres. Little hope can be seen of reducing the incidence of hospital infection unless aseptic principles are not only recognized but are properly applied.

Those who have had to deal with outbreaks of such infection in hospitals have, as a means of combating the outbreaks, urged structural alterations to the hospital wards and annexes. In these

days of stringent financial control in hospital building it is well to remember that perfect buildings do not always reflect perfect results; the methods adopted by the staff working in them are paramount. As is stated in the report 'a well equipped room was not always the scene of good work nor a badly equipped room the cause of slip-shod sterilizing practice'.

The recommendations made in the report could be undertaken quickly without great financial expenditure and would give results. The hospital authority, i.e. the Board of Governors or the Hospital Management Committee has the statutory responsibility for ensuring that the sterilizing procedures in its hospitals are as good as possible. Although the medical and nursing staffs carry out these procedures, hospital authorities will see that the co-operation of their Secretary, Engineer, Pharmacist and other lay staff is essential.

The findings of the operational research team on the working of autoclaves are alarming and worthy of particular mention. Much expensive work has been done upon the problem of anæsthetic explosions in operating rooms. While the results of explosions in operating theatres may result in a more dramatic death; inefficient or improperly operated autoclaves may affect larger numbers and the need for autoclaves to be tested and for the staff operating them to be properly trained and remunerated is urgent. This might well be considered at national level.

The future work of the operational research team into the organization of central sterile supply departments will necessarily take time. The team is considering the new methods of sterilization which are becoming available. The use of disposable equipment in central sterile supply departments is also a matter for consideration. A great deal of work remains to be done on the organization of the departments themselves. There is as yet no efficient means of sterilizing bedpans. The use of plastics in replacement of stainless steel is also a field for further investigation. Packaging of instruments and dressings is another problem. All these will entail detailed investigation in hospitals in this country and a pilot experiment in a selected hospital or group of hospitals. The team will also need to study at first hand sterilization methods in European countries, Canada and America.

In 10 years' time our methods of sterilization may well be very different from those which exist at present. Until they are, we

feel that all hospital authorities who have not already done so should undertake a systematic rechecking of all the existing methods and procedures of sterilization in their hospitals. They may find the recommendations given in the report helpful. In any case, they should not be satisfied until they have attained perfection in all their sterilizing procedures.

J. REVANS.

October, 1958

I

Introduction

1. During 1956 and 1957 the operational research team of the Nuffield Provincial Hospitals Trust were investigating the organization of central syringe services for hospitals.* As this work drew to its close, the trustees instructed their team to turn their attention next to the organization of central departments intended to supply the staff of hospitals with all their sterile equipment—not just with syringes alone. In selecting this subject the trustees knew that the designs for most new hospitals included space for such departments, although little information was available as to how these departments should be staffed and organized and how much they were likely to cost.

2. First it was necessary for the team to find out whether central sterile supply departments were necessary at all. The work of the investigating team was therefore to be divided into three phases:

Phase 1 was to be a study of present sterilizing practice in British hospitals;

Phase 2 was to consist of an investigation into the organization of centralized arrangements; and

Phase 3 was to consist of the setting up of one or two experimental departments to try out any ideas arrived at during Phase 2.

3. This report concerns Phase 1 only and the Trust's aim in publishing it is to draw the attention of hospital authorities throughout the country to the present poor state of sterilizing practice in the hope that the information contained in the report will bring about improvement of such practice. At the same time the Trust wishes to make clear that it is undertaking a long-term investigation into improved methods of sterilizing and the organization of central sterile supply departments and that findings and

* *The Planning and Organization of Central Syringe Services.* Nuffield Provincial Hospitals Trust, 1957.

recommendations will be published when the facts have been properly established.

4. To guide the team in their work a small advisory panel—listed earlier—was set up and six hospitals were selected for study. These were one London teaching hospital, three provincial hospitals, and two cottage hospitals.

5. One hospital had 15 beds; one had 50; one had 140 and the remaining three all had between 300 and 500 beds. They were thus reasonably representative as regards size. None of the six hospitals had either chronic or mental beds. They were all general acute hospitals in which all the usual specialties were represented. Three of the hospitals were in country towns; one was on the outskirts and two were in the centre of large industrial towns.

6. In planning the work of the investigation certain points had to be considered. It would have provided invaluable information if, during Phase 1, some assessment could have been made of the effect of the practices seen. If the autoclaves were not working properly or if the trolleys were being incorrectly laid, what increase in sepsis resulted? But such an assessment would have meant a major undertaking wholly impracticable with the limited resources, staff and time available. It was, therefore, decided to limit the work in Phase 1 to an objective description of what really goes on in the field of sterilization in hospitals. To this end arrangements were made to see how the nurses on the wards and in the theatres carried out their sterilizing tasks; to test the autoclaves in each of the hospitals for efficient working; to take a few time studies to give some idea of how long nurses spend on sterilization; to take some swabs to see whether articles which purported to be sterile, were sterile; and to see how contaminated dressings, linen and bedpans were dealt with. It was hoped that against such a background an informed person would be able to assess the adequacy or otherwise of the sterilizing procedures. The object of this report is to paint such a background to show people what really happens. It was originally proposed to do no more; but, as present sterilizing procedures were found to be so very inadequate, it was decided to add a section outlining steps which hospital authorities might like to take now to improve matters. The suggestions made are limited to those which will cost little.

7. In the description of present practice that follows the six

hospitals mentioned earlier are lettered A to F, but not in the order listed. The majority of these hospitals were suggested to the team by their Regional Hospital Boards. It is thought that these Boards would not willingly have suggested hospitals in which sterilizing practice was known to be of a particularly low standard. It may be concluded, then, that the practices described are typical of hospitals generally at the present time (1958). Whether they are typical of any particular hospital can only be judged by the hospital authority concerned.

8. This work, and all the observations that it entailed would not have been possible without the willing co-operation of the six hospitals. To the medical, nursing and administrative staffs of these six hospitals, the investigating team are greatly indebted. It could not have been easy for the nursing staff in particular to go about their daily work knowing that they were being closely observed, sometimes for days on end. Not only did they do this, but they did it cheerfully, and by so doing greatly eased the work of the team.

II

The Hospital Wards

General

9. *Buildings.* During the investigation every ward and the casualty and outpatient departments in the six hospitals selected for the survey were visited. As the sterilizing methods used in the casualty and outpatient departments conformed closely with those used in the wards, a separate description of these departments is not given. The 53 wards visited covered all the specialties. Some of these wards were comparatively new having been built only 25 years ago. Others were more than 100 years old. Some were in permanent buildings. Others were in war-time huts. All the wards seen except one had a clean utility room of some kind, and in this room the staff carried out their sterilizing tasks. Generally, clean utility rooms measured about 100 square feet; the floors were usually of terrazzo or linoleum; the walls were either tiled or painted with an enamel paint; and all the rooms were well lit. They were not, therefore, difficult to keep clean. A plan of a typical clean utility room, and of the equipment in it, is shown on p. 17, whilst photographs of typical rooms are shown opposite and overleaf.

The clean utility rooms were, however, not without drawbacks. First, many of them were closer to the ward beds than were the sluice rooms. As a result the nursing staff often performed in them tasks which should more properly have been done in sluice rooms. Using them for disposal of soiled dressings was common practice. Secondly, a number of them were inadequately provided with storage cupboards. This meant that surgical goods were piled on top of each other and sometimes stacked on the floor. In one hospital the excessive stocks held by the ward sisters were a contributory cause of shortage of storage space. Thirdly, they were often used as a general duty room instead of being reserved for the preparation of sterile equipment. This was especially noticeable in Hospital E where even the telephone was installed in this room. It was disheartening for the nurse, after having conscientiously closed the window and door preparatory to laying

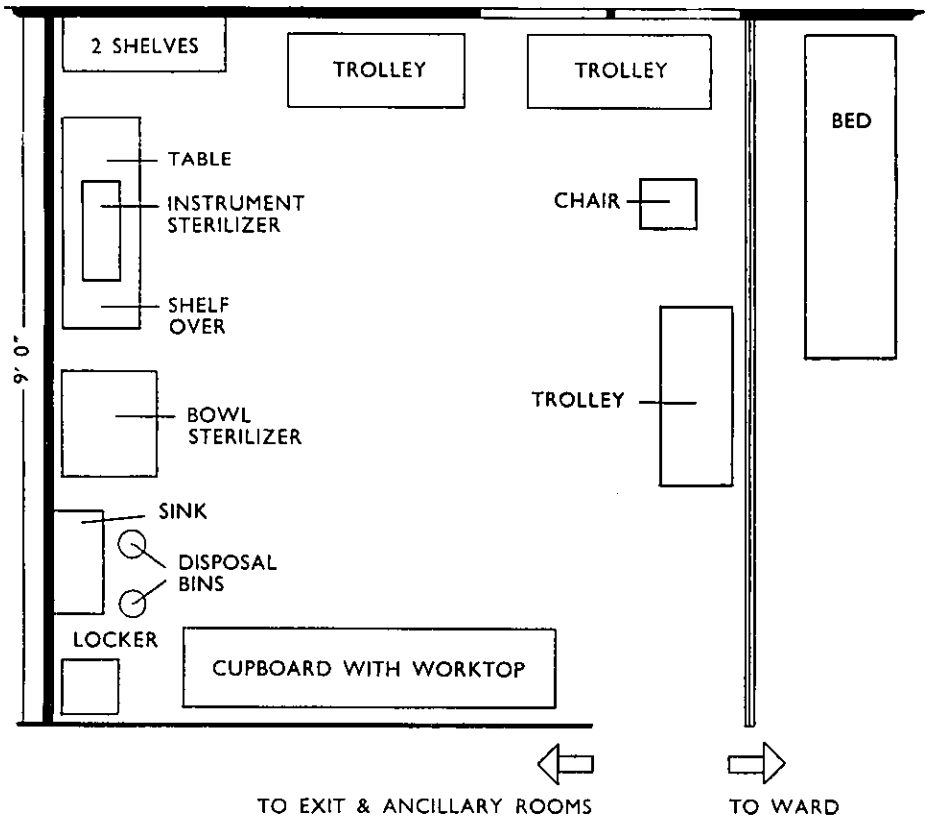
A typical clean utility room containing too much clutter for the maintenance of proper aseptic conditions

[*facing p.* 16

A corner of a ward used as a clean utility room

[*facing p.* 17

up her trolleys, to be subjected to a continuous stream of people in and out of the room to answer the telephone, deliver stores and perform other tasks. One ward in Hospital D had no clean utility room, the work normally performed in that room being done in the patients' bathroom.



A TYPICAL CLEAN UTILITY ROOM

PLAN I

10. In many of the clean utility rooms containers for sterile equipment such as jars for Cheatle forceps, instrument dishes and dressing drums, were kept on window-sills, and there were two in which the sterilizers had been installed beneath the window.

In the majority of wards in Hospital B and a few in Hospital E there were French windows in the clean utility rooms, the space directly in front of them being occupied by a table or trolley holding sterile containers. As the windows were nearly always open in the warmer weather, the chances of sterile equipment's contamination by dust from outside were increased. Photographs illustrating some of these points are shown opposite and overleaf.

11. In general, however, good sterilizing technique was seen in many rooms which were inadequate for the purpose. A well equipped room was not always the scene of good work, nor a badly equipped room the cause of slip-shod sterilizing practices.

12. *Staff.* The levels of staffing of the six hospitals varied considerably. Some were very short of staff whilst others had a staffing level as high as could reasonably be expected. This high level of staffing, however, appeared to have no more connection than good clean utility rooms with good sterilizing practice. But, low levels of staffing, resulting in too much work for the nursing staff, were clearly a factor in preventing good work. This was only to be expected, because the nurses had not enough time to spend on the many minutiæ which together make up good practice. A high standard of aseptic technique was displayed in one cottage hospital which had had fewer staff changes than most hospitals, and whose staff were sent on 'refresher' courses to a London teaching hospital as often as they could be spared. At this cottage hospital the average length of service of the nursing staff was five years.

Ward Equipment

13. *Sterilizers.* It was usual to find sterilizers in the clean utility rooms. In some there were two separate sterilizers for bowls and instruments; in others there was one sterilizer in which they were boiled in separate compartments. A few wards had more than two sterilizers. In one cottage hospital one sterilizer served two small wards. Sterilizers were heated by gas, electricity or steam. Of the 66 sterilizers seen, 7 (six in Hospital A and one in Hospital D) were gas, 28 were electric and 31 were steam heated. They are considered in that order.

14. The staff of Hospital A considered that their gas sterilizers were dangerous, having recently been the cause of three accidents. On one occasion masks had been placed to dry on the sterilizer

A result of inadequate storage capacity

[*facing p.* 18

Sterile equipment exposed to dust from outside

[*facing p.* 19

lid and the strings allowed to hang over the sides. Later these masks were discovered in flames. On another recent occasion, after a sterilizer had been turned down, a nurse turned it on full. Flames leapt up round the sides of the sterilizer and set fire to the apron of the sister who was standing alongside. On a third occasion, a nurse dusting pipes near the base of the sterilizer had her eyebrows burned. The staff at Hospital A were anxious, therefore, to get rid of their gas sterilizers. Accidents did not occur if electric or steam sterilizers were used.

15. In hospitals in which no steam was supplied to the wards, electrically heated sterilizers were used. None of them was thermostatically controlled. Most of the bowl sterilizers were, however, equipped with a rheostat to assist in the control of boiling, but a nurse had to turn a knob to work it. If she forgot—not an unusual occurrence—the sterilizer might boil dry. Hospital D had fitted an automatic safety device to prevent this happening. Few instrument sterilizers had any rheostat and they had either to boil furiously or to be switched off. The times taken for sterilizers to boil varied from ward to ward; but, generally, the large ones took between half an hour and two hours and the small ones about half that time. It was therefore necessary for staff in surgical wards, in order to keep the water in their sterilizers as near boiling point as possible, to switch them on at frequent intervals throughout the 24 hours.

16. Of the three types, the steam sterilizers in Hospitals E and F appeared to be the most convenient to use. Boiling point was reached more quickly—about 20 minutes for 10 gallons of cold water—and sterilizers could be safely turned off when temporarily out of use, as it took only three minutes for them to return to the boil. Against this convenience must be set the cost of bringing steam to all the wards. This may well be as much as £30,000 for a 500-bedded hospital.

17. Five out of the six hospitals were in 'hard' water districts. In these conditions the maintenance of sterilizers presented a very real problem. They were usually cleaned with wire-wool pads or a coarse scourer in the middle of the day when most of the treatments had been done. Some wards cleaned their sterilizers every other day; in other wards they were cleaned weekly and water added when necessary. Occasionally a fitter from the Engineer's Department was asked to de-scale the insides of the

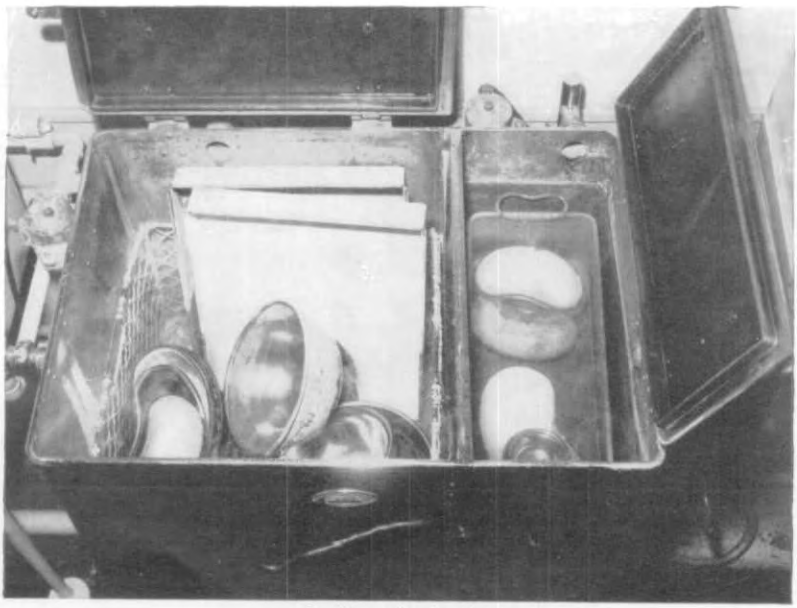
sterilizers with hydrochloric acid or other agent. In a busy surgical ward in Hospital A a nurse, about to prepare sterilized equipment for a dressings round, found the water in the sterilizer cloudy and the contents filled with chalky sediment. The equipment was quite unfit for use. The sterilizer had to be emptied and cleaned, the contents washed and re-boiled. This took one and a half hours and caused great inconvenience to the nursing staff. Even in the 'soft' water district of Hospital D, sterilizers were emptied daily and cleaned with scouring powder in order to keep them in proper condition. Two photographs are shown opposite comparing a properly maintained sterilizer in Hospital D with a scaled sterilizer from Hospital A. In Hospital E an attempt had been made to eliminate scaling by providing demineralized water for all ward sterilizers. But the still could not possibly satisfy demands and it was therefore decided to supply the instrument sterilizers only, the pharmacist maintaining that a weekly clean and change of demineralized water in the instrument sterilizers would be sufficient. When fully effective this policy may reduce the work of cleaning instruments but time is taken up distributing water, and the task of cleaning bowls still remains.

18. It is generally accepted that boiling will kill vegetative bacteria if it is carried out properly for five minutes.* Even this is not always achieved. On two occasions whilst some time studies were being undertaken, a pair of forceps and a syringe were taken out of a sterilizer by one nurse about 50 seconds after they had been put into it by another. It is inevitable that under the present system of ward sterilization equipment is improperly sterilized from time to time. No system was seen whereby the dangers caused by several nurses using one or two sterilizers could have been avoided.

19. *Bowls.* The majority of bowls used in the wards were of stainless steel. Each ward appeared to have sufficient for its needs. But, again, due to the 'hard' water, these bowls required considerable maintenance. They were usually cleaned with wire-wool pads or abrasive powder; but, to prevent scale from forming on the bowls, this had to be conscientiously done every day and even then scale was liable to form under the rims. If the bowls were not cleaned every day scale formed quickly. A photograph of

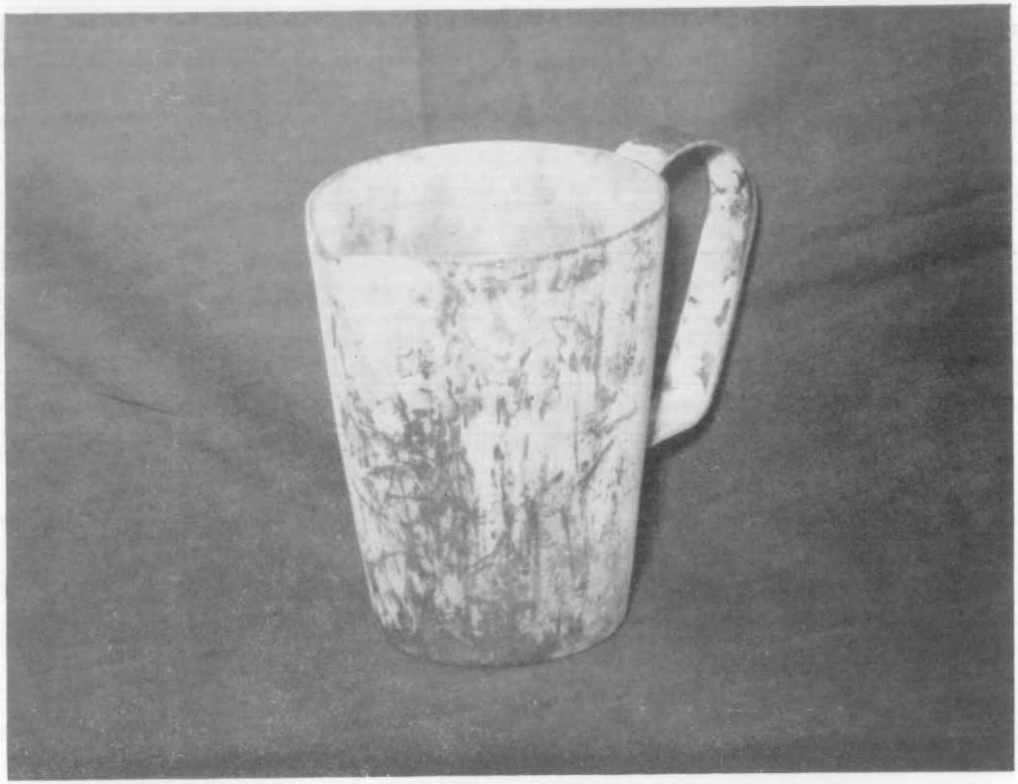
* Report of the Central Pathological Committee of the Ministry of Health on the Sterilization of Hospital Equipment, Ministry of Health, 1954.

Well maintained



Badly maintained

[*facing p.* 20



Stainless steel measure after five months' use

[facing p. 21

a stainless steel pint measure which had not been properly maintained is shown opposite. This measure had been in use in Hospital A for only five months. It is not known whether or not scale allowed to form in this way impedes sterilization. But since stainless steel is intended to provide a smooth surface it cannot be good practice to allow it to become roughened.

20. Two nursing practices both of which might impede efficient sterilization were fairly common. First, bowls were not always submerged and, secondly, they were often tightly stacked before being sterilized. Nurses sometimes avoided stacking the bowls because if they did so it was difficult to extract them singly with Cheatle forceps. It was not appreciated that the stacking of bowls might create air pockets between them which could impede sterilization.

21. *Instruments.* Wards usually held enough surgical instruments for their needs and on the whole these were in good condition. If time permitted, they were given a weekly clean with abrasive powder or plate polish and the joints were lubricated with oil. Sterilization consisted of boiling for a period of 2 to 20 minutes followed by storage in a covered lint-lined dish containing an antiseptic solution. The variety of these solutions was very noticeable. They included: pure lysol, sudol or dettol; lysol or dettol 5 per cent. in spirit; formalin solution; 90 per cent. or 70 per cent. spirit; metaphen; domittol (1 per cent. domiphen bromide, 0·2 per cent. chlorhexidine); or hibitane. Except in Hospital E, ward sisters seemed free to use what they wanted and there was little uniformity even within a single hospital. In some wards these solutions were used as sterilizing agents rather than storage media. On these wards it was the view that, provided they were left in long enough, instruments could be sterilized by being immersed in such solutions. Hospital D was the only hospital in which the dishes and their lint linings were sterilized in addition to the instruments themselves. This was carried out weekly, and more frequently in the maternity unit. In the other hospitals these dishes were usually washed weekly and the storage media renewed, though sometimes this might be done only fortnightly. The lids of the dishes were often defective. In some instances lids were too small to fit the dishes. In others broken lids had been mended with adhesive tape. Yet again, handles were missing, leaving holes. (In one case this had been partly hidden by a

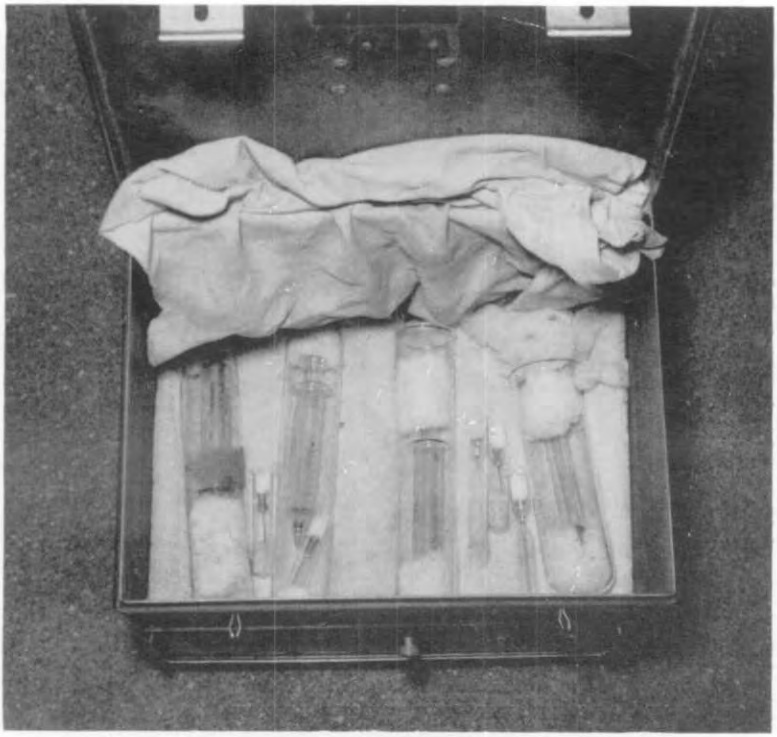
drawing pin.) Several dishes were covered with improvised lids of cardboard covered with waterproof adhesive tape. Such defects were seen in all hospitals. The nursing staff excused these faults by saying that it was difficult to obtain new lids. In five of the six hospitals, wards kept a selection of small pieces of sterile equipment in jars and dishes. This practice entailed routine maintenance work which the majority of staff had no time to do. The result was that much of the equipment was left in an unsatisfactory condition. But in Hospital F these pieces of equipment were only boiled when required.

22. In most cases dirty bowls and instruments were cleaned between dressings by rinsing under the tap. The aid of a nail-brush—not always one kept specially for the purpose—was sometimes enlisted for the instruments. Hospitals D and E were generally more thorough. In order to protect the nursing staff from infection grossly contaminated equipment was usually left to soak before being cleaned and sterilized. But the antiseptic chosen and its strength were often unsuitable for the purpose.

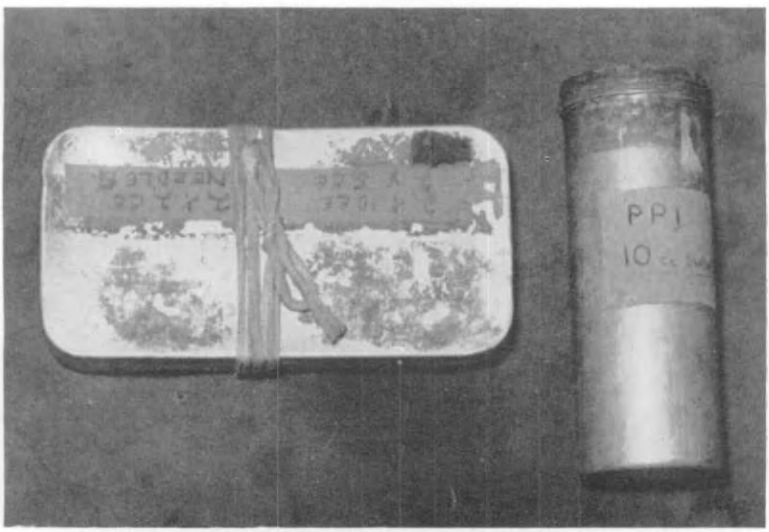
23. Cheatle forceps were usually boiled daily and the storage solution renewed, but sometimes boiling was done once or twice a week. Suitable containers for Cheatle forceps were not always available in many of the wards. Jam jars of varying capacity, pint measures, etc., were seen. The former are difficult to boil, especially the 7 lb. variety, and are in consequence never boiled. From the appearance of some of them even the cleaning was perfunctory. Pint measures were too small to hold sufficient fluid to cover the Cheatle forceps adequately. In Hospitals E and F although many of the wards had properly designed stainless steel containers for their forceps, the amount of antiseptic fluid in them was barely enough to reach the joints. Often, too many Cheatle forceps were crammed into the jars and it was, in practice, impossible for one pair to be extracted without contaminating them by touching the handles of the others. Cleaning these forceps before boiling usually consisted of rinsing under the tap, or it might be omitted altogether.

24. *Syringes*. Half of all the sterile treatments done in hospitals involve the use of a sterile syringe.* The importance of sterilizing each syringe properly cannot therefore be over-emphasized. Yet

* Established from data collected as part of the long-term investigations into sterilizing methods.



Assembled syringes packed for autoclaving. Steam will be unable to penetrate these syringes



Syringes enclosed in tin containers. Steam will be unable to penetrate the containers

[*facing p.* 22

Defective latches, repaired with safety pins and tape

The metal casing has been holed

[facing p. 23

the sterilization of syringes left much to be desired. Three different methods were employed:

(*a*) the syringes were boiled in the ward sterilizers; or
(*b*) they were packed and sent down to be autoclaved; or
(*c*) they were processed in a central syringe service.

(*a*) The boiling of syringes in the wards was criticized in *The Planning and Organization of Central Syringe Services** as follows:—

> 'First, such decentralized arrangements do not lend themselves to adequate supervision. Contaminated equipment may be added to a sterilizer just before syringes required for use are taken out, or the period of boiling may be less than the recommended minimum of five minutes. Secondly, sterilizers are sometimes left boiling for a long time with consequent waste of gas or electricity. Thirdly, maintenance of syringes and needles is often perfunctory, breakage rates are high and needles never sharpened, but used until blunt and then thrown away. Lastly, boiling is known not to be fully effective against spores.'

These faults were often observed in the wards where syringes were still boiled. It was further noticed, particularly in Hospitals B and D, that, even if the syringes had been properly boiled, they were often subsequently stored in dishes containing insufficient fluid to cover them.

(*b*) Hospitals B, D and F had attempted to get over the inadequacies of boiling by sending their syringes to be autoclaved. But there was no standard pack; each ward being more or less free to develop its own. In Hospital B syringes were sent to be autoclaved assembled, rolled in gauze and packed into a small drum. In Hospital D three or four syringes were placed dismantled in a cake tin which itself was wrapped in linen. In Hospital F syringes were either wrapped dismantled in gauze and packed loosely into a drum or lubricated, assembled and packed into test tubes, aluminium containers or old *tulle gras* tins. Test tubes, containers and tins were often stuffed with tight wads of cotton wool and

* *The Planning and Organization of Central Syringe Services*, Nuffield Provincial Hospitals Trust, 1957.

sealed before sterilization with adhesive tape. Some photographs of such packs are shown opposite p. 22. It did not seem to be appreciated that, if syringes are to be sterilized by autoclaving, the steam in the autoclave must be allowed to reach the surfaces of barrels and plungers. This it cannot do properly if the syringes are autoclaved assembled, unless a vacuum as high as about 29 inches Hg is drawn. It becomes even more difficult if they are lubricated before being assembled. Anything in the nature of tight wads of cotton wool acts as a further barrier to the steam. Some suggestions are made in Appendix E as to how syringes might be packed if they are to be autoclaved.

(*c*) As there was a central syringe service in one of the hospitals, it may be assumed that the syringes sterilized there were more certainly sterile than those processed on the wards or autoclaved in unsuitable packs. But even these were sent up to the wards several packed in a single container. These 'multi-packs' have the following disadvantages:—

(i) when the box is first opened all the contents are potentially unsterile;
(ii) the nozzles of the syringes are usually not adequately protected against bacterial contamination;
(iii) there is no certainty that the syringes in the middle of the pack have had the same heat treatment as those on the outside.

In this hospital there was the further disadvantage that the multi-packs were also left too long on the wards before being exchanged, thus further increasing the risks of contamination.

25. *Drums.* The large, round, plated drum with perforations in the side wall was the type most widely used for the sterilization of towels, gowns and dressings. A few drums of the non-perforated square type were seen, principally at Hospitals E and F. Hospital drums of all kinds were often found to be unsatisfactory for any of the following reasons:

(*a*) some had been knocked about and damaged;
(*b*) some had been lined with unsuitable materials;
(*c*) some were too tightly packed.

(*a*) A small proportion of the drums on all wards had been damaged so that the lids fitted badly and the perforated metal bands did not fit snugly to the sides of the drums. A chain and

A useless container for sterile dressings

An ill-fitting lid allowing the contents to protrude

[*facing p.* 24

A drum too big for its purpose and overlined with expensive surgical dressings

A burnt and unmanageable linen lining

[*facing p.* 25

hook was the type of catch generally fitted, but the sterilizing attendants complained that these were not reliable and came undone easily. A few of the catches were inefficient and on some drums parts of them were missing, safety pins and string being used to keep the catches closed. The knob which prevents the perforated band from over-shooting the correct position was missing on some drums thereby leaving a small hole. Some photographs of damaged drums are shown opposite pp. 23 and 24.

(*b*) Linings were often unsuitable and the report on those in Hospital E is typical of the state of linings in all the hospitals seen during the study:—

> 'Various kinds of linings are used. Some of the wards use a double thickness of unbleached calico supplied by the linen room; some make lint or gamgee linings on the wards; others use incontinent pads; clinical sheets; or sometimes nothing at all. Linings, where used, are not periodically laundered but remain in the drums until they disintegrate. In order to assess the way in which drums had been lined, an inspection was made of 150 about to be autoclaved. Of these 150 drums, 60 were lined with surgical dressings, 40 with double thicknesses of calico, 4 were fitted with wire racks whilst 46 had no lining at all.'

Some photographs of drum linings are shown opposite.

(*c*) The technique of packing drums was often at fault. It did not seem to be fully appreciated that dressing drums must be loosely packed. The report on Hospital B may be quoted as typical of what was seen generally:—

> 'Of the two hundred drums examined, a small proportion (12 per cent.) of them were tightly or badly packed. Bad packing may be attributed to:—
>
> (i) too many articles squashed into one drum;
> (ii) gowns and towels folded to an inconvenient size for the drum;
> (iii) mackintoshes packed separately from towels (not many were placed in a drum, but by reason of their weight lay very tightly together);
> (iv) a mackintosh and two towels folded in one pack, and coarse huckaback hand towels used because of a shortage

of dressing towels. Both of them made tight and bulky packs;

(v) bundles of swabs and small skin towels tied tightly around the middle with string.'

Some photographs of badly packed drums are shown opposite and overleaf.

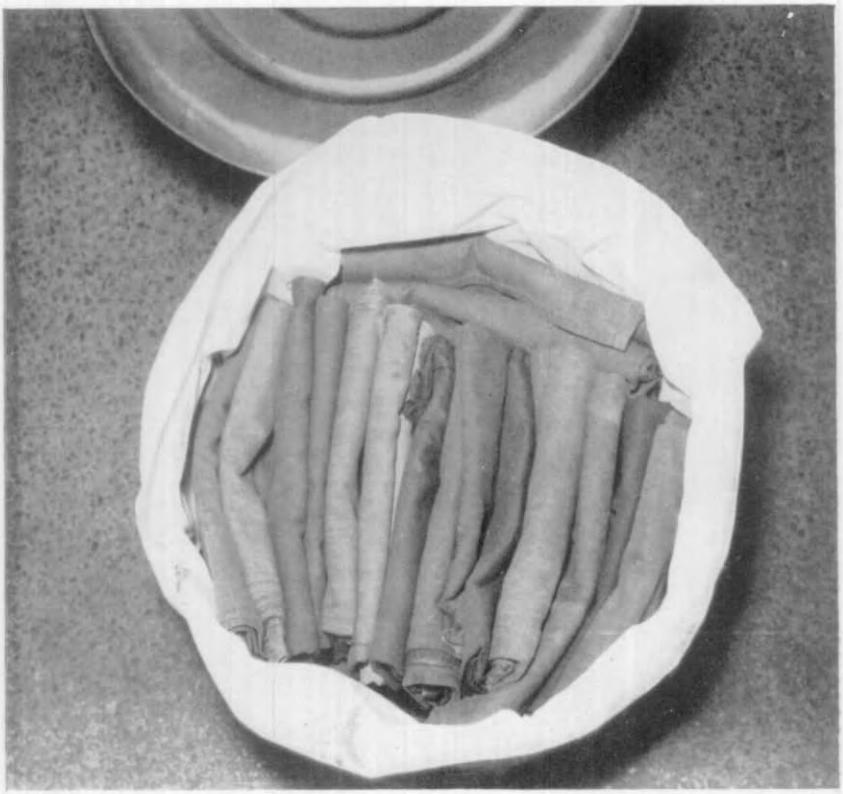
26. Sometimes the drums were not properly delivered. The chief cause of this was the natural inclination of hospital porters to save themselves work. Thus in Hospital B the porters carried sterile and unsterile drums on the same trolley at the same time. There might not have been any great harm in this, were it not for the fact that the only way they then differentiated between sterile and unsterile drums was to feel them to see which were warm. A surer way is to seal them after sterilization with a lead or similar seal bearing the date. This is the practice in some hospitals. In Hospitals E and F the autoclave attendants did not take drums into the clean utility rooms, but left them outside in the corridor. In Hospital E they were placed on special shelves above ground level; but in Hospital F they were left on window-sills, benches or the floor. Some photographs of drums awaiting collection by the nursing staff of the wards are shown opposite p. 30. It was observed that sterile and unsterile drums were often waiting in the passages for collection for hours at a time.

27. Sterile drums not in use were stored on shelves in the linen cupboard, in a general-purpose stock-room or in the clean utility room. In Hospital B a label bearing the date of sterilization was affixed to each drum before it was returned to the ward. This label, however, was not always referred to before a drum was brought into use. In the other five hospitals no indication of the date of sterilization was given. In only one ward were there any arrangements to ensure that drums would be used in their correct order. Ward staff seldom checked their stock of drums. In busy wards this might not matter, since one drum was rarely in use for more than a day. But in the quieter wards dressing drums might wait any time up to three weeks before use; and, once in use, might last for a week. It was found that special drums, which were used infrequently, might have been sterilized up to 12 weeks prior to the day on which they were needed. In two wards at Hospital B two drums, one containing an intravenous cutting-down set and the other gloves, had last been sterilized six and seven

Overpacked and with too big a lining

Too tightly packed and without lining

[*facing p.* 26



Too tightly packed

[facing p. 27

months previously. In the other hospitals it was usual, but not always the rule, that special drums should be sterilized weekly. One ward in Hospital E sent its drums for re-sterilization twice weekly, another considered monthly re-sterilization sufficient. In Hospital E little attention was paid to the re-sterilizing of tins of *tulle gras*. Patients with dirty wounds were usually allotted their own tin, but the remaining tins might have been unsealed and in day-to-day use for up to four months.

28. *Dressing Trolleys*. Four of the six hospitals followed the practice of laying a separate dressing trolley for each patient. But in three Hospitals A, C and D, no uniform system had been decided upon. Each ward had introduced its own variations, and student nurses moving from one ward to another often had to unlearn and relearn small details of sterile preparation. Only in Hospital E was one method used universally throughout the wards.

29. In Hospitals B and F, where one sterile setting was used for up to 15 different patients, the procedure was as follows. The lower shelf was laid with bandages, lotions and miscellaneous articles, as well as receptacles for dirty dressings, bandages and instruments. In Hospital F a dry jar holding Cheatle forceps was added. The upper shelf was swabbed with antiseptic (using Cheatle forceps and a sterile dressing) and laid in the traditional way with or without a sterile towel underneath. As many towels, dressings and instruments as possible were laid in order to save frequent replenishment. A sterile setting might thus remain in use up to two and a half hours. In order to prevent contamination of sterile equipment laid in this way, it is necessary to have two nurses to do a patient's dressing.* In none of the hospitals were there enough nurses to allow two to be employed in this way and an adequate aseptic technique was never seen to be achieved. In some wards, particularly the plastic surgical wards, where there were many dressings to be done, the trolleys were prepared about a quarter of an hour after the ward cleaning had been completed and might then be left, sometimes by an open window, for an hour before they were used. In many of the hospitals, if one of the medical staff wished to see a patient's dressing taken down, a trolley would be laid up and covered with a sterile mackintosh. In one instance this trolley was set aside under the telephone and

* Medical Research Council, Memorandum No. 11 (Revised edition, 1951). H.M.S.O.

adjacent to the hand basin and the roller towel, all of which were in constant use, until the doctor arrived five hours later.

30. In Hospital F wards carried out treatments in a side room appropriated for the purpose rather than at the patient's bedside. This was clearly a better arrangement provided the side room was suitable for the task. Unfortunately, this was not always the case.

Time Studies

31. No information was available as to how much nursing time each day was taken up by the general sterilizing work outlined above. To get some idea of this, time studies were made in 15 wards of Hospital B and in 8 wards of Hospital F. The tasks were divided into four categories:—

(1) Cleaning and sterilizing of Cheatle forceps and their containers;
(2) Laying dressing trolleys;
(3) Clearing dressing trolleys and cleaning bowls, instruments and sterilizers;
(4) Miscellaneous tasks connected with sterilization but not covered by 1–3 above.

The sterilization tasks listed above were studied on each of the 23 wards between 8 a.m. and 1 p.m. during which time most of the day's sterilizing work is done. The sample of wards included surgical, medical, thoracic, plastic and ear, nose and throat specialties. The average number of beds was 20. The times shown in Table I on p. 29 give some indication of how much time during a day nurses spend on sterilizing work.

As expected the maximum times of column (*b*) came from surgical wards and the minimum times of column (*c*) came from the medical wards. Hospital B had a number of plastic surgery wards. In these the times spent on sterilizing tasks were the greatest; and it was the wards of this specialty which caused the greater maximum times observed at Hospital B. The average time spent on sterilizing tasks in this sample of 23 hospital wards was 91 minutes (one and a half hours) per day although, as seen in Table I, the nursing staff on some busy surgical wards spent as long as 207 minutes (over three hours) per day on sterilizing work of some kind.

TABLE I. *Time Spent on Sterilizing Procedures in the Wards*

Task (*a*)	*Maximum time seen to be taken per ward on any one day (mins.)* (*b*)		*Minimum time seen to be taken per ward on any one day (mins.)* (*c*)	
	Hospital B	*Hospital F*	*Hospital B*	*Hospital F*
1. Preparation and sterilization of Cheatle forceps .	9	4	1	2
2. Laying dressing trolleys .	58	34	3	7
3. Clearing dressing trolleys and cleaning bowls, instruments and sterilizers .	117	42	12	4
4. Miscellaneous tasks connected with sterilization .	23	52	1	1
TOTAL . . .	207	132	17	14

Disposal

32. It is essential to comment on the arrangements for the disposal of:—

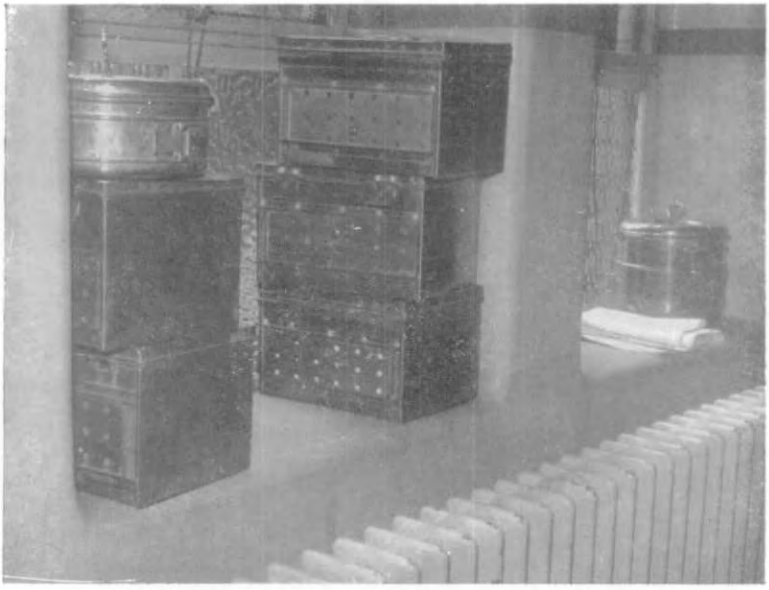
(*a*) soiled dressings;
(*b*) linen; and
(*c*) excreta,

since, if they are not efficient, they may adversely affect sterilization.

(*a*) *Dressings.* In nearly all the wards soiled dressings were collected in a bowl—not always kept specially for this purpose—which sometimes contained a little pure dettol or a solution of carbolic. The bowl was invariably placed on the lower shelf of the dressing trolley. A few wards in Hospital A used paper bags instead of bowls. In Hospitals C, D and E bowls were emptied after each dressing. But at Hospitals B and F bowls were emptied when full, rather than at the end of each treatment. In Hospital E about half the wards kept soiled dressings in a bin in the sluice room; but this was not the practice in any of the other hospitals where soiled dressings bins were to be found in clean utility rooms. Photographs showing soiled dressings bins in clean utility

rooms are shown opposite page 31. During a time study of the use made of clean utility rooms in Hospital B it was recorded that between 8 40 a.m. and 2 20 p.m. all the dressings on a plastic surgical ward were deposited in the clean utility room, no nurse going into the more distant sluice room for any purpose whatsoever. Soiled dressings bins in the majority of the hospitals visited were fitted with liners. When the sluice or clean utility rooms were inconveniently sited, these liners were removed when full and carried, uncovered, through the wards to a large dustbin. In Hospital E all bins were supposed to be lined with paper bags which were removed twice daily by a porter and taken in a dustbin to the disposal centre. Responsibility for re-lining the bins was not clearly defined and in consequence paper linings were sometimes missing. In these instances, the porter either removed the contents with his gloved hands or tipped them into a half-filled bag taken from some other bin. The cleanliness of soiled dressings bins was variable, depending very much on the conscientiousness of the ward orderlies.

(*b*) *Linen.* In all the hospitals, except Hospital A, the soiled linen was counted and booked by the nursing staff before it was put into canvas bags, which were then placed in laundry baskets. There were not always sufficient canvas bags and often dirty laundry had to go straight into the basket. Generally the hospital authorities demanded that sluiced linen should be dried before being sent to the laundry. This presented a problem as there was nowhere to do it other than the confined space of the sluice or bathroom, or, as in Hospital E, on rails specially erected on the balcony. With the exception of Hospitals B and D which removed linen from the wards on only three days a week, it was the practice to make daily (Sundays excepted) collections and deliveries. On Monday mornings the accumulation of two days' soiled linen was difficult to accommodate. This state of affairs was considerably aggravated at Hospital B where there was no collection between Friday and Monday, and wet linen was to be seen hanging from every available piece of furniture and fitting and sorted piles of dried linen were heaped on the floor. This was specially noticeable in wards in which there were a large number of incontinent patients. Photographs of dirty linen in sluice rooms and on balconies are shown opposite pp. 32 and 33. Often comparatively clean articles like disinfected bed mackintoshes were to be seen



Sterile and unsterile drums in main corridor awaiting collection.
(At the bottom of the central pile the perforations in the drum are open)

Sterile drums in main corridor awaiting collection by ward staff

[*facing p.* 30

Examples of the present practice of disposing of contaminated dressings in clean utility rooms

[*facing p.* 31

hanging side by side with sluiced linen. In none of the hospitals were nurses and orderlies supplied with protective clothing to wear when handling dirty linen.

(*c*) *Excreta.* Hand-operated bedpan washers were fitted in the majority of the ward sluices. The following difficulties occurred when using such a washer. The washer door was often unwieldy to open, although it was operated with the aid of a pedal. Shutting the door was particularly difficult. Nurses complained that:—

(i) using the washer was a lengthy process if it was to clean the bedpan efficiently;
(ii) they had to stand by for nearly two minutes operating the water levers and, even then, it might be necessary to use a mop to complete the cleaning process;
(iii) the jets of water spread fæcal matter under the rims of the bedpans where it could not readily be seen.

These complaints were confirmed by independent observation. In practice bedpans were placed in the washer, given perfunctory squirts of cold and hot water and then left in the washer. The next nurse to use the washer then removed the bedpan and replaced it on the shelf without inspecting it. This resulted in a high proportion of visibly contaminated bedpans. In Hospital E time studies were made of the cleansing process, and in the majority of cases a bedpan was exposed to the water jet for only ten seconds. Often nurses used hot water first when flushing out a bedpan. This coagulated the proteins and in effect baked the fæces on to the bedpan. Most of the sluice rooms contained a sluice sink and nurses often used this rather than the washer. A mop or brush was used to clean the bedpans. This method was quicker, easier and more efficient than a machine. Attention paid to the maintenance of mops and brush containers was somewhat haphazard, and the replacement of bedpan covers was in nearly all cases left to the discretion of a junior nurse or orderly.

33. A total of 166 bedpans were inspected at Hospital B. Of this number: 64 (38·5 per cent.) were contaminated to a greater or lesser extent with fæcal material; 53 (31·9 per cent.) were stained; and 49 (29 per cent.) were clean. At Hospital E a similar count disclosed that about 20 per cent. were contaminated and the number of clean bedpans was proportionately higher.

Swabs

34. At the conclusion of the observations on the wards a number of swabs were taken of sterilized equipment, such as Cheatle forceps and their containers, syringes and instruments and their containers and the insides of drum casings. The results of the cultures of these swabs are shown in Table II opposite p. 35.

A hazardous and time-consuming way of dealing with soiled and contaminated linen

[*facing p.* 32

A hazardous and time-consuming way of dealing with soiled and contaminated linen

[*facing p.* 33

III

The Theatres

General

35. In general the theatres were better built, better provided and better maintained for sterilizing purposes than the clean utility rooms in the same hospitals. What was more important, however, was that the theatre staff were always more sterilization-minded than the ward staff. This is only to be expected since so much of their training is to this end, and since they suffer fewer distractions from their sterilizing tasks than their colleagues in the wards. As a result sterilizing practices were seen to be carried out more efficiently than on the wards.

36. In the cottage hospitals, the operating theatre had usually been fitted up in a room off the main hospital corridor. All the theatres had a separate sterilizing room, although in some instances it had to perform the dual function of sterilizing and sluice room. Most of the theatres were either tiled or painted with enamel paint. All the floors were of terrazzo and were washed daily. In most theatres the staff gave a weekly wash to as much of the walls as they could reach, whilst the hospital painters washed the whole of the walls and ceilings periodically. Two theatres in Hospital B had not had any overall wash of this kind for the past 18 months. In the same hospital water leaked through the roof of one of the anæsthetic rooms on to any sterile trolley that might be beneath. In this same theatre the staff had to wage continual war against cockroaches. These instances were however isolated; and, in general, theatres were in good buildings in a good state of repair, even if some of them were short of ancillary rooms.

37. Of the 18 theatres visited during the survey, there was only one block of twin theatres in Hospital B in which the air was conditioned and a positive pressure maintained. This block had been built as recently as 1954. These ideal conditions had not however been achieved without trouble. The air-conditioning plant had been badly installed, a break in the air route having been

overlooked. This resulted in an outbreak of staphylococcal infection traceable to the contaminated air being driven into the theatres. The remaining theatres in this and the other hospitals had to manage as best they could with open windows or windows covered with zinc mesh or butter muslin. Generally the windows of the sterilizing rooms in which the trolleys were laid for operations were unscreened, even if the theatre windows were guarded. Usually there was an extractor fan to carry away steam from the sterilizers, and in Hospital E it was coupled with an intake fan, thus avoiding the need for open windows. In Hospital B the theatre sisters and medical staff, having recently been confronted with a case of surgical tetanus, had had their attention focussed on the dangers of faulty ventilation. Ground-level open ventilators, deemed to be the cause of the trouble, had been bricked up. In order to maintain a closer check on invading organisms, settle plates were exposed regularly in all the theatres and sterilizing rooms in this hospital and window-sills were swabbed.

Equipment

38. Some of the theatres had their own autoclaves. But the functioning of autoclaves, even when they are part of a theatre suite, justifies separate consideration. The results of the examination of all autoclaves are therefore dealt with later in Section IV.

39. There were enough bowls and instruments for the needs of each theatre. They were of stainless steel, and were well maintained. It was the practice in some theatres to boil the bowls separately for each operation. In others all bowls were boiled together; the sterilizer was then switched off and the bowls used until the supply was exhausted, when the process was repeated. Four of the hospitals covered by the survey dealt satisfactorily with the sterilization of their instruments. But in Hospital C the dishes in which the theatre scissors were stored were too small to hold sufficient formalin to cover them, and some of the handles and blades were above the level of the liquid. In the same hospital new Bard Parker blades were 'sterilized' with the coating of white grease applied by the manufacturer still on them.

40. The section earlier in the Report describing the state of repair and packing of drums applies also to theatre drums. More attention was, however, paid to their cleanliness and most of the theatres had rooms which were used solely for the storage of

TABLE II. *Numbers of Sterile and Unsterile Swabs*

	Hospital A	*Hospital B*			*Hospital C*			*Hospital D*			*Hospital E*	*Hospital F*				
		Swabs	*Sterile*	*Unsterile*	*Swabs*	*Sterile*	*Unsterile*	*Swabs*	*Sterile*	*Unsterile*		*Swabs*	*Sterile*	*Unsterile*	*Proportion of unsterile swabs*	
WARDS																
Article																
Cheatle forceps and the insides of the containers		20	17	3	2	1	1	5	3	2		12	12	—	6/39	
Syringes and the inner surfaces of the dishes		16	11	5	2	2	—	6	5	1		27	24	3	9/51	
Instruments and the inner surfaces of the dishes		15	13	2	2	2	—	7	6	1		4	4	—	3/28	
Drum casings (inside)		17	10	7	4	3	1	—	—	—		22	19	3	11/43	
TOTAL WARDS	No swabs taken	68	51	17	10	8	2	18	14	4	No swabs taken	65	59	6	29/161	18% unsterile
THEATRES																
Article																
Cheatle forceps and the insides of the containers		7	4	3	2	2	—	3	2	1		6	6	—	4/18	
Syringes and the inner surfaces of the dishes		1	1	—	—	—	—	—	—	—		2	2	—	0/3	
Instruments and the inner surfaces of the dishes		7	7	—	3	3	—	2	2	—		5	5	—	0/17	
Drum casings (inside)		2	1	1	2	2	—	—	—	—		6	4	2	3/10	
TOTAL THEATRES		17	13	4	7	7	—	5	4	1		19	17	2	7/48	12·5% unsterile
WARDS AND THEATRES		85	64	21	17	15	2	23	18	5		84	76	8	36/209	17% unsterile

IV

The Autoclaves

General

44. *Buildings.* Only in the smallest of the six hospitals covered by the survey was there no autoclave room. In this hospital all autoclaving was done in the theatre suite. In the other hospitals the quality of the autoclave accommodation varied considerably. Sometimes the autoclave room was a clean, tiled or enamel-painted, room off a hospital corridor, sometimes the decoration and fittings had clearly been long neglected. About one third of the autoclave rooms seen came in this latter category. Some photographs of the interiors of autoclave rooms are given opposite and overleaf. Although hygienic conditions were clearly unobtainable in this type of room it by no means followed that the most efficient procedure always took place in the best equipped room. Sometimes failure to attend to a tiny detail imperilled efficient working. An example of this was in the autoclave room of Hospital B where a ventilator, immediately above the table on which drums were stacked before and after sterilization, provided a perch for birds and the floor and the table in front of the autoclave were soiled with bird droppings. A piece of wire netting over the ventilator now excludes the birds. In this same autoclave room the three sets of double doors were nearly always open.

45. *Staff.* In Hospital C the autoclaving was done by a retired ward sister who came to the hospital for this purpose on two afternoons a week. At other times it was done by the nursing staff. In all the other hospitals except one, the autoclaving attendants were male porters. In Hospital F the autoclave attendant was a woman who carried out her task most conscientiously. One of the features which the survey revealed was the lack of supervision of autoclave attendants. All too often they had been taught their work by the head porter or the orderly from whom they took over. Most of them had some difficulty in answering the question: 'To whom are you responsible for your work ?' Some held themselves responsible

drums. In most hospitals the stocks of sterile drums were checked weekly and, if necessary, re-sterilized.

41. In Hospitals A, B, D and E the arrangements for the laying up of theatre trolleys were satisfactory. But the practice in Hospital C was poor. In order to avoid overcrowding when the theatre was in use during the afternoon, all the sterile equipment required for the first three operations was laid out during the morning. The sterile settings were covered with sterile towels and left for approximately three hours until the first was used. The third setting was sometimes not used until six hours later if previous operations had taken a long time. In this hospital a cap and a mask were the only protective clothing worn when the trolleys were being laid.

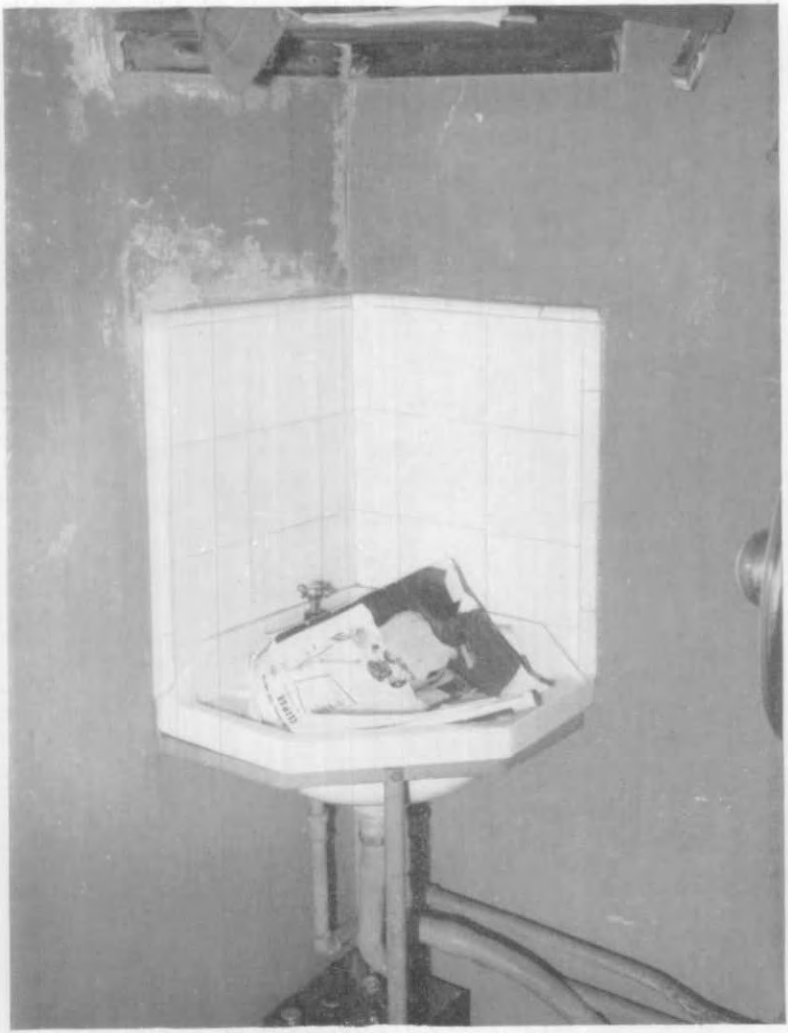
42. Hospital F had only one combined sluice and sterilizing room to serve two theatres. They had evolved a system of their own to reduce congestion in this room when both theatres were busy. They laid out a 'buffet' of sterile bowls, drums and other equipment in each theatre at the beginning of each day's work. From this 'buffet' scrubbed nurses helped themselves to what they required. Instruments were laid up separately for each operation. It is easy to criticize a system whereby bowls and drums required for later operations are exposed, even remotely, to infections from earlier operations in the same theatre. But this solution was probably better than running greater risks through congestion in the small sluice and sterilizing room.

Swabs

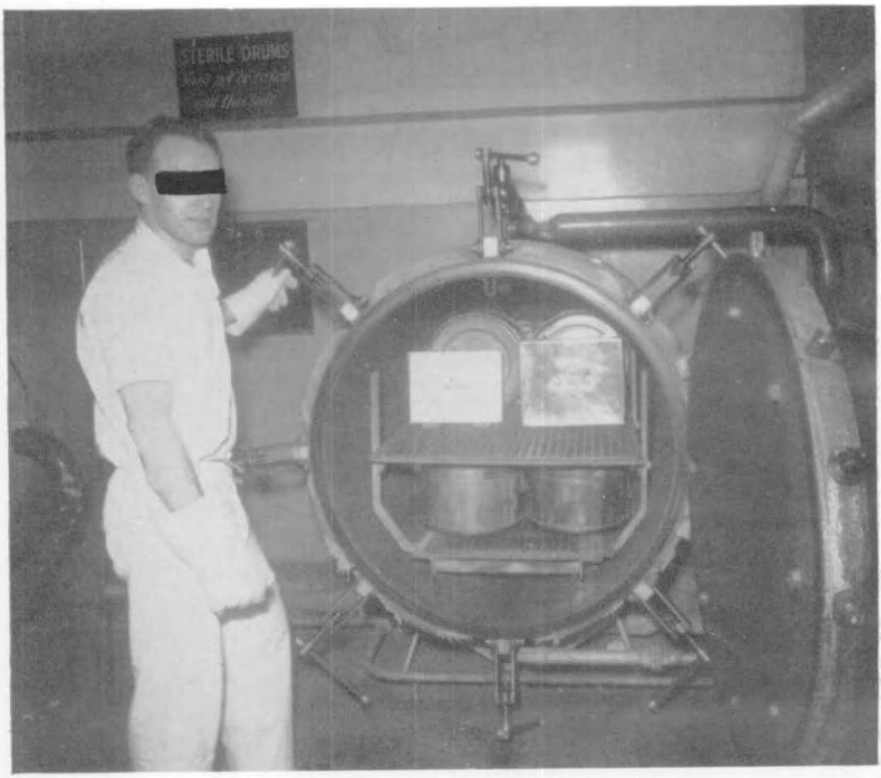
43. At the conclusion of some of the surveys an independent observer took a number of swabs of sterilized equipment in the wards and theatres. Equipment swabbed consisted of the insides of jars and dishes containing Cheatle forceps, the insides of dishes containing instruments and syringes and the inner surfaces of drum casings. The swabs taken were delivered immediately to the Central Pathological Laboratory at Portsmouth where they were cultured in the usual manner. The results of the cultures of the swabs are shown in Table II opposite. It will be noticed that 18 per cent. of the ward and 12·5 per cent. of the theatre cultures were unsterile.

Dirty and unsuitable conditions for autoclaving

[*facing p.* 36



A corner of an autoclave room. The room was in a state of disrepair and the wash-hand basin used as a receptacle for refuse



The notice above the attendant's head reads:
STERILE DRUMS MUST NOT BE TAKEN OUT THIS SIDE

[*facing p.* 37

to the head porter, some to the theatre sister, some to the hospital secretary and some to the engineer. At Hospital A the autoclave attendant was inclined to feel that he owed allegiance to the matron, but this was mainly because he also drove the nurses' bus. It will be shown later that when the autoclaves were not functioning properly, it was often due to the way in which they were being worked, rather than to other causes. The autoclave attendants' failure was often the result of the hospital authorities' failure to define clearly who was responsible for their supervision.

46. The autoclave attendants' standard of aseptic discipline often left much to be desired. Thus, in Hospitals B and E the autoclave rooms were divided into sterile and unsterile sides. In Hospitals A, C, D and F there was no such distinction. In Hospital B the porters used the unsterile side only for loading and unloading the autoclaves. They had found this less laborious. In Hospital E it depended on which attendant was using the autoclave whether the two rooms were used correctly or not; often one room only would be used for loading and unloading the drums; alternatively, the rooms might be used the wrong way round. As a result, sterile and unsterile drums were sometimes to be found on the same side of the double-ended autoclaves. Opposite is a photograph of one of the autoclave attendants in Hospital E about to unload one of the autoclaves on the unsterile side. No special protective clothing was worn by the attendants and usually an old rag was used for handling the hot drums. Only in Hospital D was the attendant seen to wear a mask while carrying out his task. The attendant in Hospital A invariably kept his old cloth cap on his head whilst working the autoclave.

Equipment

47. Each of the autoclaves in Hospitals B, C, D, E and F was examined separately and its functioning tested. The results of these tests are summarized in Table III opposite p. 38. All the autoclaves, except No. 11, were worked by the partial pre-evacuation method. No. 11 was worked by downward displacement alone. In this Table everything that is shown to be satisfactory has been printed in *black* and everything unsatisfactory in *red*. It will be seen that (excluding autoclaves 17 to 24 which were small theatre instrument autoclaves only) out of the 17 autoclaves tested (autoclave

No. 1 was not tested) eight were functioning satisfactorily, four were in the doubtful category and five were clearly unsatisfactory. The causes of the failure of the autoclaves in the doubtful and unsatisfactory categories are tabulated below:—

Autoclave No.	*Cause of Failure*
2	Primarily due to faulty steam supply, but bad design and bad operation also factors. This machine could not have functioned satisfactorily.
8	Pressure too low and time too short to do more than disinfect bedding.
9	Operated at too low a pressure.
12	Inefficient air removal was the cause of failure. The machine was badly operated because there was no automatic chamber drain and only one inadequate vacuum was drawn for the preliminary removal of air.
13	Faulty operation a primary factor but inefficient air removal due to bad installation also a contributory cause.
14	Operated wrongly, chamber drain closed.
15	Operated wrongly, chamber drain closed, but faulty steam supply probably a secondary factor.
16	Operated wrongly, chamber drain closed, but faulty steam supply probably a secondary factor.
25	An old machine with low initial vacuum and out-of-date design.

Of the nine inefficient autoclaves (the doubtful autoclaves are included in the inefficient category since no hospital can afford to run an autoclave unless it is known, beyond doubt, to be functioning properly) the failure of six (Nos. 8, 9, 13, 14, 15 and 16) was wholly or partly due to bad operation; the failure of four (Nos. 12, 13, 15 and 16) was wholly or partly due to bad installation; the failure of one (No. 2) was mainly due to bad installation partly to bad design and the failure of one (No. 25) to mechanical inefficiency and old age. In 1955 Dr. Bowie found

TABLE III. *Summary of Autoclave Tests*

Satisfactory results are marked in black, unsatisfactory results are in red.

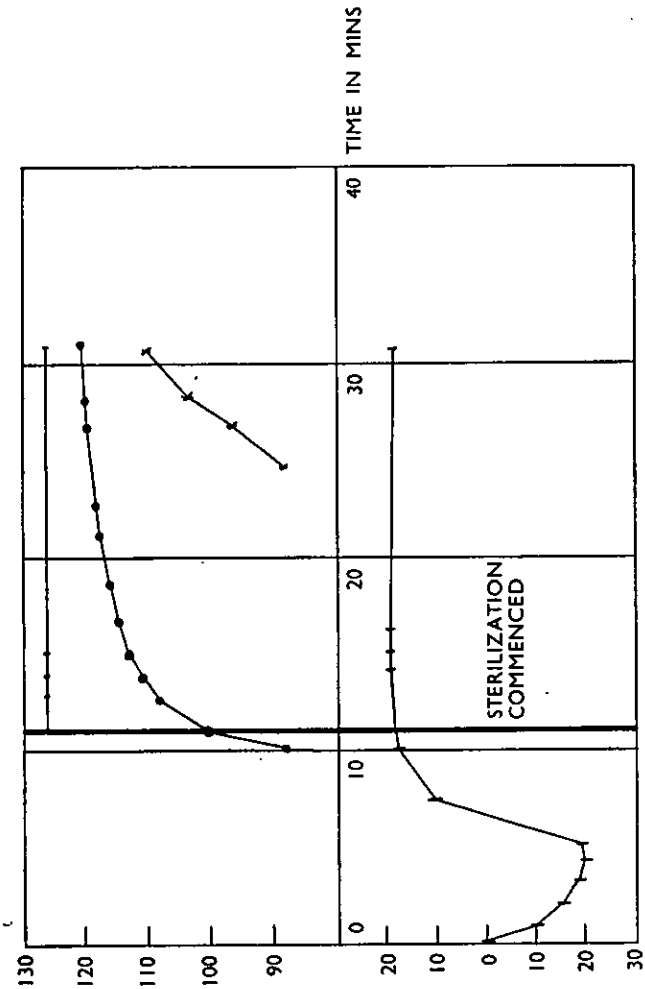
Autoclave	*Usual Load*	*Sterilizing pressure in chamber. lb. per square inch.*	*Exposure time (Defined in Appendix A)*	*Penetration time*	*Holding time and safety period*	*Colour Change of Browne's Tubes*		*Survival of Spore Cultures*		*Air Filters*	*Operated*	*Equipment Efficiency*	*Sterilizing Efficiency*	*REMARKS*
						Yellow Spot	*Black Spot*	*B. Subtilis*	*B. Stearo-thermophilus*					
HOSPITAL 1						NOT TESTED								A new autoclave was awaiting installation at this hospital, but was not installed at the time of the survey.
HOSPITAL 2	Theatre dressings	20 lb.	30 mins.	Not reached	Nil	Incomplete	Almost unchanged	Killed	Survived	Satisfactory	Wrongly	Unsatis-factory	Unsatisfactory	Faulty steam supply. A re-test gave similar results. Only one low vacuum used.
3	Theatre instruments	20 lb.	30 mins.	6 mins.	24 mins.	Complete	Complete	Killed	Killed	Satisfactory	Satisfactorily	Unsatis-factory	Satisfactory for instruments	Faulty steam supply.
4	Theatre bowls	20 lb.	60 mins.	4 mins.	56 mins.	Complete	Complete	Killed	Killed	Satisfactory	Satisfactorily	Doubtful	Satisfactory for bowls	In the same built-in unit as autoclaves 2 and 3 and receiving steam from the same source. 56 minutes is an excessive period for sterilizing bowls.
5	Dressings	20 lb.	30 mins.	4 mins.	26 mins.	Complete	Complete	Killed	Killed	Satisfactory	Satisfactorily	Satisfactory	Satisfactory	
6	Dressings	20 lb.	45 mins.	20 mins.	25 mins.	Complete	Complete	Killed	Killed	Satisfactory	Wrongly	Satisfactory	Satisfactory	Exposure time unnecessarily long. Correct loading (i.e. placing the drums on their sides) and better operation could have reduced this.
7	Dressings	20 lb.	45 mins.	18 mins.	27 mins.	Complete	Complete	Killed	Killed	Satisfactory	Wrongly	Satisfactory	Satisfactory	Exposure time unnecessarily long. Correct loading (i.e. placing the drums on their sides) and better operation could have reduced this.
8	Mattresses and occasionally gloves and instruments	5 lb.	30 mins.	28–29 mins.	1–2 mins.	Incomplete	Almost unchanged	Killed	Survived	Satisfactory	Wrongly	Satisfactory	Satisfactory for mattresses Unsatisfactory for gloves and instruments	This autoclave is only intended to achieve a pressure of 5 lb. p.s.i. and to maintain it for 30 minutes to disinfect mattresses.
9	Gloves and other rubber goods	5 lb.	30 mins.	2 mins.	28 mins.	Complete	Incomplete	Killed	Survived	Satisfactory	Wrongly	Satisfactory	Unsatisfactory	This autoclave was efficient but it was being worked at a pressure of 5 lb. p.s.i. only instead of the 10 lb. p.s.i. required.
10	Glassware and instruments	20 lb.	30 mins.	0–7 mins.	23–30 mins.	Complete	Complete	Killed	Killed	Satisfactory	Satisfactorily	Satisfactory	Satisfactory	Identical with 9, but used at a higher pressure.
11	Sputum mugs	20 lb.	30 mins.	15 mins.	15 mins.	Complete	Complete	Killed	Killed	Satisfactory	Satisfactorily	Satisfactory	Satisfactory for sputum mugs	Operated by downward displacement and only intended for sputum mugs.
HOSPITAL 12	C Dressings	25 lb.	15 mins.	13 mins.	2 mins.	Complete	Complete	Killed	Killed	Unsatis-factory	Wrongly	Unsatis-factory	Doubtful	The slow rate of steam penetration was due to the inefficient system of removing air. There was no automatic chamber drain.
HOSPITAL 13	D Dressings	20 lb.	30 mins.	16 mins.	14 mins.	Complete	Complete	Killed	Killed	Satisfactory	Wrongly	Satisfactory	Satisfactory But margin of safety low	Only one low vacuum used. Inefficient air removal due to 'U' bends in chamber drain piping; this caused excessive condensation in the pipe which impeded the removal of air.
HOSPITAL 14	E Dressings	20 lb.	20 mins.	Not reached	Nil	Incomplete	Almost unchanged	Survived	Survived	Unsatis-factory	Wrongly	Satisfactory	Unsatisfactory	Sterilizing period not long enough. Wrongly loaded and operated. Chamber drain was kept closed.
15	Dressings	20 lb.	20 mins.	Not reached	Nil	Unchanged	Unchanged	Survived	Survived	Unsatis-factory	Wrongly	Doubtful	Unsatisfactory	Sterilizing period not long enough. Unsatisfactory steam supply to chamber. Wrongly loaded and operated. Chamber drain was kept closed.
16	Dressings	20 lb.	Presumed 20 mins.	PRESUMED AS FOR AUTOCLAVE 15						Unsatis-factory	Presumed wrongly	Presumed doubtful	Presumed unsatisfactory	Installed alongside autoclave 15. Worked in same way. Same steam source. Chamber drain was kept closed.
17 to 24	Bowls and instruments	15 lb.	30 mins.	NOT TESTED		Complete	Complete	Killed	Killed	Not examined	Satisfactorily	Satisfactory	Satisfactory	Materials not dried after sterilizing.
HOSPITAL 25	F Dressings	20 lb.	30 mins.	18 mins.	12 mins.	Complete	Complete	Killed	Killed	Satisfactory	Satisfactorily	Doubtful	Satisfactory But small margin of safety	Old equipment being used efficiently to obtain a maximum sterilizing effect; but wasteful of steam and man hours in the process.
26	Dressings and gloves	20 lb.	30 mins.	12 mins.	18 mins.	Complete	Complete	Killed	Killed	Satisfactory	Satisfactorily	Satisfactory	Satisfactory	As for autoclave 25.

autoclaves to be functioning inefficiently.* But the machines examined by this team appeared to be better designed than those seen by Dr. Bowie, inasmuch as they all had condensate and air discharge drains from the base of the chamber. Autoclave No. 12 (Table III) was not fitted with an automatic trap and the drain was worked by a hand valve. The manufacturer's instructions for this operation were 'open occasionally.' Unskilled operation seems now the predominating cause of inefficiency. The operating faults were nearly always those which hindered the removal of air from the dressings. The containers were placed in such a way as to retain air, whilst the chamber drain was not correctly opened or not opened at all. When the chamber drain was functioning the results were generally satisfactory.

48. Attention has already been given elsewhere to questions of autoclave design.* There is also little to be gained by discussing autoclaves that are just old and worn out. But only two of the nine autoclaves were unsatisfactory for this reason. Bad installation and bad operation, both of which are preventable, were the major causes of trouble and it may be of value to examine them in greater detail. Autoclave No. 13 was an instance of bad installation. This autoclave was made by a well-known firm of manufacturers and was installed by the hospital engineer as recently as September 1957. It could not be fitted into a room with an outside wall. It had to go into an inside room next to the theatre, and the chamber drain pipe was taken some 25 feet to connect with an outside drain. The path of the copper tube from the autoclave chamber to the outside drain is shown opposite page 42. As steam entered the pipe from the chamber it condensed and water accumulated in the pipe where shown on the diagram. This water amounted to some six pints (about 7 lb. in weight) and, each time the autoclave was used, this water had to be pushed out before air could be evacuated from the chamber. It is hardly surprising that the air was only partly removed and sterilization below standard.

49. But the commonest cause of autoclave failure was bad operation. Again, an example may help to illustrate what was happening. The failure of autoclave No. 14 was wholly attributable to bad operation. This autoclave also was manufactured by a well-known firm and was installed some 20 years ago. It was used

* Bowie, J. H. (1955) Pharm. J., 174, 473, 489.



TEMP. EQUIVALENT OF STEAM PRESSURE

PRESSURE

TEMP. CENTRE AT BASE OF DRUM (DRUM PLACED FLAT)

TEMP. SIDE AT BASE OF DRUM

(the exceptionally low temps. at this point in drum are probably due to localized air pockets).

DIAGRAM I

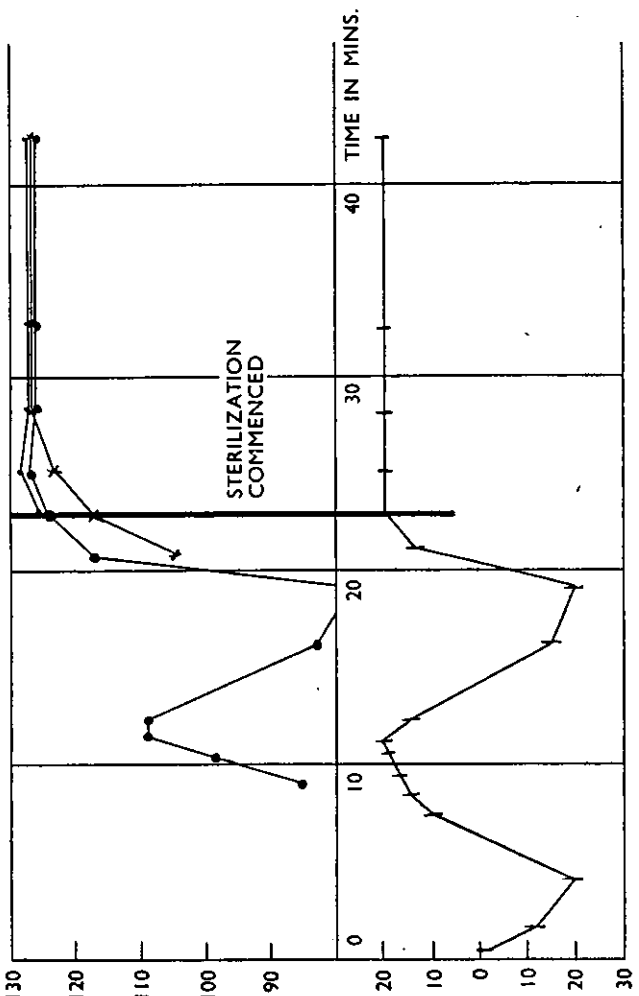

STERILIZATION COMMENCED
TIME IN MINS.
130
120
110
100
90
0
10
20
30
40
20
10
0
10
20
TEMP. EQUIVALENT OF STEAM PRESSURE
PRESSURE
TEMP. AT CENTRE OF DRUM
TEMP. AT SIDE OF DRUM (DRUM PLACED ON ITS SIDE)

DIAGRAM 2

solely for the autoclaving of theatre drums. The manufacturer's instructions stated that the valve which operated the chamber drain should be opened during sterilization. This is essential since, if the valve is shut, residual air cannot escape. Yet the autoclave attendants in this hospital operated the autoclave with this valve closed and maintained that these were their instructions. As a result, instead of being full of steam, the autoclave chamber contained large quantities of air. The evacuation of air from this autoclave and the free flow of steam into it, were further impeded by these other operating faults:—

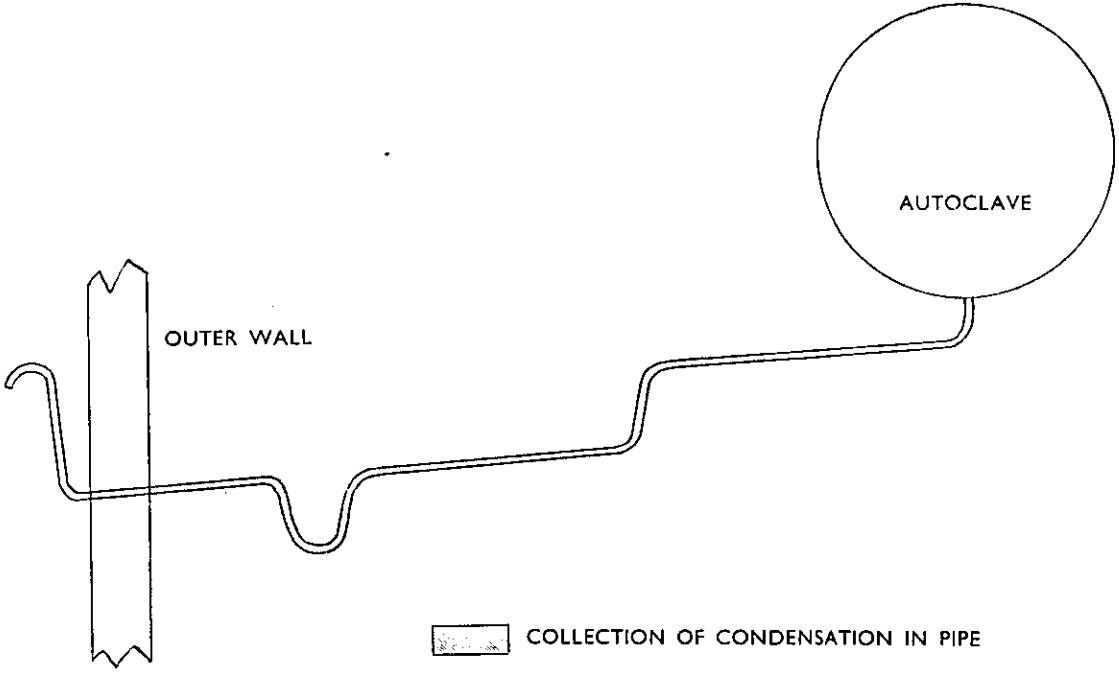
(*a*) only one vacuum of 20 inches Hg was drawn instead of two (this was, however, in accordance with the manufacturer's instructions which, in this respect, were out of date);
(*b*) the shelves of the autoclave were too close together to allow the drums to be put on their sides although this position facilitates the penetration of steam.

On the previous pages are two time-temperaturecurves arrived at by the methods outlined at Appendix A and showing, first, the temperatures in this autoclave when operated by the autoclave attendants; and, secondly, the temperatures in the same autoclave when operated properly under the instructions of the investigating team. All the autoclaves whose functioning is summarized in Table III, with the exception of autoclave No. 2, could have been made to function satisfactorily if skilled operation and proper supervision had been forthcoming.

50. After the autoclaves in Hospital E had been tested, it transpired that their unsatisfactory working had been known, or at least suspected, for a very long time. Bacteriological tests which had been made in them had not always been satisfactory. Plans had been considered for replacing them all. Yet no steps had been taken to ensure that they were operated properly. No one would accept responsibility for this. At the time of the survey in this hospital the vital responsibility for ensuring that the autoclave worked properly was undefined.

Air Filters

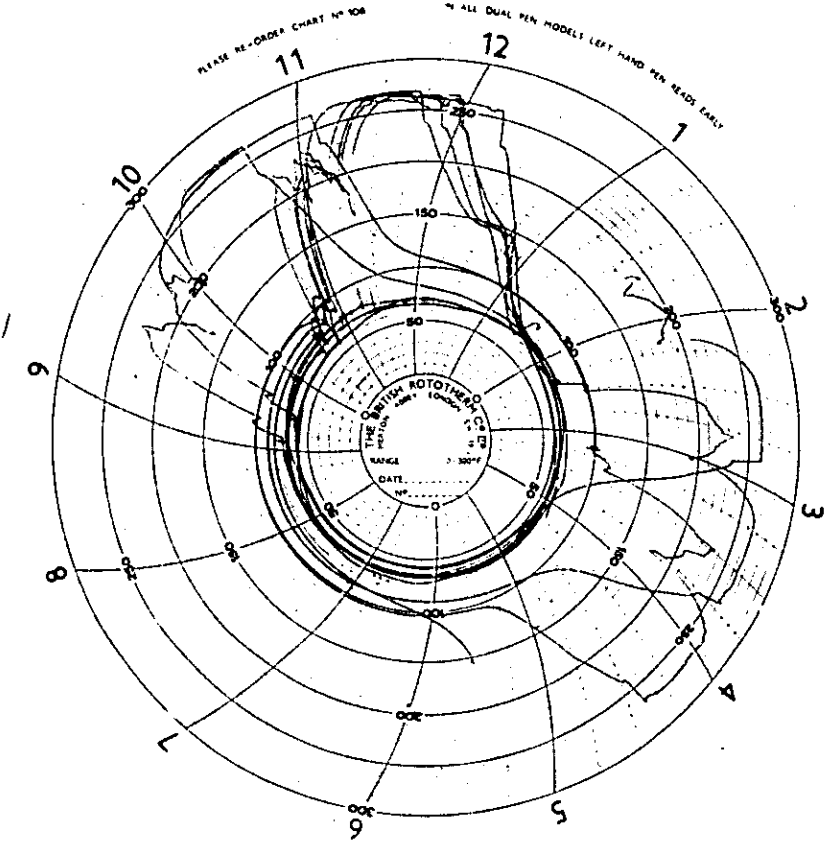
51. All the dressing autoclaves had cotton wool filter cups attached to the air inlet pipe except in Hospital E. In this hospital no attempt was made to filter the air. In Hospital C the quantity



CHAMBER DRAIN PIPING

DIAGRAM 3

[facing p. 12


PLEASE RE-ORDER CHART No 108
IN ALL DUAL PEN MODELS LEFT HAND PEN READS EARLY
12
1
2
3
4
5
6
7
8
9
10
11
THE BRITISH ROTOTHERM Co LTD
LONDON
RANGE
DATE
No.

[*facing p.* 43

of cotton wool in the air-filter cup was too small to make an effective filter. The term 'satisfactory' for the filters used in Table III is only intended to be applied to the condition and maintenance of the existing filter. The term in no way implies that the investigating team regard this type of cotton wool filter as satisfactory for modern autoclaves. A study of Table II discloses that 26 per cent. of the swabs taken of the insides of drum casings were unsterile. The probability is that the drums had been recontaminated after sterilization.

Routine Tests

52. It will be generally agreed that hospitals ought to know how their autoclaves are functioning. To enable them to do this certain routine tests have been devised:—

(*a*) Temperature or combined temperature and pressure recording charts;
(*b*) Browne's tubes;
(*c*) Routine bacteriological tests.

(*a*) *Recording Charts.* Pressure-recording apparatus was fitted on eight of the 17 autoclaves, although on one of these it was broken and had been out of use for some months. Temperature-recording apparatus was provided on only two of the 17 autoclaves. On one of these autoclaves it was broken and had been out of action for some months. It was common practice in many of the hospitals to use their pressure-recording charts more than once and one hospital used its charts so frequently as to make them illegible. A photograph of an illegible chart is shown opposite. It was exceptional for any hospital to date and file its charts properly for reference. These charts were seldom studied by anyone in a position of responsibility.

A thermometer in the chamber drain is an essential part of autoclave equipment. Only five of the 17 autoclaves had thermometers in the chamber drain. Of these five, two were so awkwardly placed that it was necessary to get down on one's hands and knees to read them, and one was broken and useless. Only two, out of the five thermometers, were thus working satisfactorily.

(*b*) *Browne's Tubes.* Hospitals B and D used Browne's tubes in theatre and ward drums. Hospitals A, E and F used them in

theatre drums only. Hospital C did not use them at all. But only in Hospitals D and F were they placed properly in the centre of the contents of the drums rather than on the top.

As all theatre drums in Hospital F did not contain a Browne's tube, 'Klintex' papers were used. These papers change colour when subjected to steam. They therefore indicate that the drum in which they have been put has been autoclaved.

(*c*) *Bacteriological Tests.* Hospital F was the only hospital to attempt any routine bacteriological tests. This hospital also used heat-resistant spores. But even in this hospital the autoclave attendant was left to position the drum containing the spores and he did not know the importance of placing it in one of the less favourable parts of the autoclave, i.e. at the bottom. In Hospitals A, B, C, D and E no routine bacteriological tests were carried out.

V

Discussion and Suggestions

General

53. As mentioned in the introduction to this paper there is reason to think that the sterilizing practice in these six hospitals may be typical of what happens in most hospitals at present, and that, if so, there may have been some general decline in standards in recent years. It would be a disservice to hospitals if the faults of their sterilizing practices were to be laid bare without any suggestions being made as to how matters might be put right. Action seems called for under two heads:—

(*a*) *Short Term:* Action which hospitals can take now without incurring appreciable financial expenditure; and
(*b*) *Long Term:* Action involving changes in organization as part of a long-term plan.

It is too early to make any suggestions under (*b*) above. Further research is needed. Nevertheless, it is hoped that some immediate short-term suggestions will help hospitals, particularly if they involve no appreciable financial expenditure. The short-term suggestions are designed:—

(*a*) to improve the working of hospital autoclaves;
(*b*) to introduce a substitute for hospital drums;
(*c*) to improve the technique for the sterilization of syringes;
(*d*) to raise the standard of routine practices;
(*e*) to better the methods for the disposal of dirty dressings, linen and bedpans;
(*f*) TO UNDERLINE THE NEED TO DEFINE RESPONSIBILITY.

(*a*) *Autoclaves*

54. When these six hospitals were first visited the staff of some of them had doubts about their autoclaves. But it came as some surprise to them that many of their autoclaves should prove to be as inefficient as they were. This was certainly, in part, due to a

failure clearly to define responsibility. This is most important and it is suggested that responsibility for the supervision and control of the autoclaves should rest with the pathologist or bacteriologist.

He will require to assure himself that the autoclaves are functioning efficiently. To do this it is suggested that he should personally carry out a 'full-dress' test, along with the hospital engineer, once a year. This test, it is suggested, should be similar to that described at Appendix A. But much can go wrong between such comprehensive checks; and it is therefore suggested that the bacteriologist should also carry out a monthly check with chemical indicator tubes inside a test package. This monthly test might be combined with a test for the recontamination of dressings during the drying process. Details of these tests are given at Appendix B.

In order to do all this the pathologist or bacteriologist will probably require an assistant. It is suggested, therefore, that a supervisor for the autoclaves should be appointed. This person may be a member of the laboratory staff, a theatre sister or other suitable person. As an independent check on the functioning of the autoclaves is essential, the person appointed should be other than the autoclave attendant. Whoever is appointed should be conversant with the technical principles involved and be given the opportunity of learning about the theory and practice of sterilizing. The duties would consist of seeing that instructions are carried out, that records are properly kept, and that sterilizer attendants and their holiday reliefs are trained. In addition to the tests carried out by the pathologist or bacteriologist the supervisor should, it is suggested, carry out a daily test with a package containing an indicator tube. This should be studied by him together with the routine control charts which it should also be his duty daily to inspect.

It has been mentioned earlier that there is a danger of sterile and unsterile drums becoming mixed. To prevent this happening it is suggested that the nurse requires some simple indication to show that her returned containers have been through the autoclave. Details of some indicators suitable for this purpose are also given in Appendix B.

55. These safeguards against autoclave faults and human failings are more comprehensive than most in current practice. The additional work involved is negligible when compared with the risks that are being taken with imperfectly functioning or

An autoclave room in a continental hospital

[facing p. 47

badly manipulated autoclaves. The cost of the equipment described at Appendix A and of the different types of indicator suggested at Appendix B is trivial. If the autoclaves are found to be inefficient in some way, an attempt should be made to upgrade them by an engineering overhaul and the fitting of traps, etc. If hospitals can find the money, an electrically operated high-vacuum pump may be installed in place of a steam ejector for evacuating air. The cost of pumps is of the order of £300. But in a busy sterilizing department this cost should be offset by a considerable saving in time and steam. To be effective the vacuum must be obtained quickly and be of a high order. The sterilizer manufacturer should be consulted before such modifications are made.

56. If possible autoclave rooms should have sterile and unsterile sides. If accommodation does not allow of such an arrangement, then some other means of segregating sterile from unsterile containers should be made. Walls should be plastered and painted, floors made easy to keep clean and a sink with running hot water provided. Such things will encourage autoclave attendants to keep their rooms better than those illustrated in photographs facing p. 36. Opposite is a photograph of an autoclave room in a continental hospital. This is the sort of room at which to aim. Something is also required to improve the status and working conditions of autoclave attendants. They are responsible for carrying out the sterilization of hospital dressings, gloves and other equipment. Yet they have had no proper training in their task and at present receive a rate of pay less than that of gatekeepers. It is suggested that the training and rates of pay of autoclave attendants should be reviewed at national level with the object of making both more appropriate to the responsibilities they shoulder.

(*b*) *Drums*

57. The preceding paragraphs have used the word 'container' rather than 'drum' because a substitute for the hospital drum, which is an unsatisfactory piece of equipment, is overdue. During the investigation a visit was made to the central sterile supply department which had been improvised at the Cambridge Military Hospital, Aldershot, to meet problems with which they were faced at the time of the Suez crisis. Here, amongst other containers, cardboard boxes were being used. These seemed to have advant-

ages over drums. But, as there was some doubt about the rate of steam penetration through the boxes further tests were carried out at the Bristol Royal Infirmary. These showed that steam was able to penetrate a tightly packed cardboard box better than a similarly packed dressings drum. The cardboard boxes gave excellent protection against bacterial contamination of the contents after sterilization. The tests are described at Appendix C.

58. It was apparent, however, that the boxes used by the Cambridge Military Hospital could be improved upon for general hospital use, and the matter was accordingly taken up with a firm of cardboard manufacturers. As the result of their work a specially designed box has been produced intended specifically for hospital autoclaving. This box is collapsible and simple to erect. It requires only a few staples to hold it together and these are put in by the manufacturer before the box reaches the hospital. Further, in the process of folding and erecting the box the corners have been so designed as to form a tight seal against any access of dust. A full description and photographs of the box are given in Appendix D.

In view of the advantages of these cardboard boxes it is suggested that hospitals should consider taking them into use instead of drums. It should cost nothing to introduce these boxes; since, although there will be an annual charge for them, this should be less than the amount annually spent by hospitals on the maintenance and repair of drums.

(c) Syringes

59. Half of all sterile treatments in hospitals involve an injection.* The importance of a properly sterilized syringe is therefore clear. In this survey the least satisfactory syringes were those which were processed on the wards. The most satisfactory way to improve the sterilization of syringes is for hospitals to institute central syringe services. But, if hospitals cannot afford these services immediately, perhaps they can at least afford to buy enough syringes for all of them to be autoclaved centrally. If this is to be attempted, the syringes must be properly packed. Details of how this can be done are given at Appendix E. It will, however, be appreciated that this is no permanent solution

* Established from data collected as part of the long-term investigations into sterilizing methods.

to the problem. The syringes will still have to be assembled in the wards under unsterile conditions and this entails some risks. It should therefore be the aim to start a syringe service as the first step in centralizing the sterilization in hospitals.

(d) Routine

60. Earlier in this report there was mention of the variety of sterilizing routines in use, even within a single hospital. The need to improve sterilizing routine is of major importance. It is hoped here to show some of the ways in which this can be done, although in the space of this report it is impossible to cover all of them. In five out of the six hospitals there was no uniform sterilizing procedure. It varied from ward to ward. As a result the nurses in training were continually having to learn and unlearn matters of detail. These details should be uniform throughout a hospital so that once learned they are never forgotten and would, in time, become second nature to all concerned. It is suggested that the laying of a separate setting for each patient should have special consideration; it is also suggested that the more traditional complications of trolley laying could be simplified and the number of dishes reduced. Much of the equipment still laid out could be dispensed with. Such details could be worked out at the sisters' periodical meetings and then approved by the hospitals Control of Infection Committee. In all hospitals except Hospital E, ward sisters were free to use whichever disinfectant they chose. Even in this hospital where a list had been drawn up of standard disinfectants and their respective uses, the nursing staff still did not appreciate that chemical disinfection does not necessarily sterilize; vegetative bacteria may be destroyed but the bacterial spores remain. This is a serious limitation that must be borne in mind when disinfecting instruments which can only be adequately sterilized by saturated steam or dry heat.

61. Porters in some hospitals have a habit of delivering sterile containers only as far as the passage outside the wards. In the passages these containers are more easily contaminated than in the comparative security of the appropriate ancillary room. It is suggested that all sterile containers be delivered into the ward unit.

(e) Disposal

62. Some hospitals already put dirty dressings into paper bags the moment the dressings come off the patient. This system seen

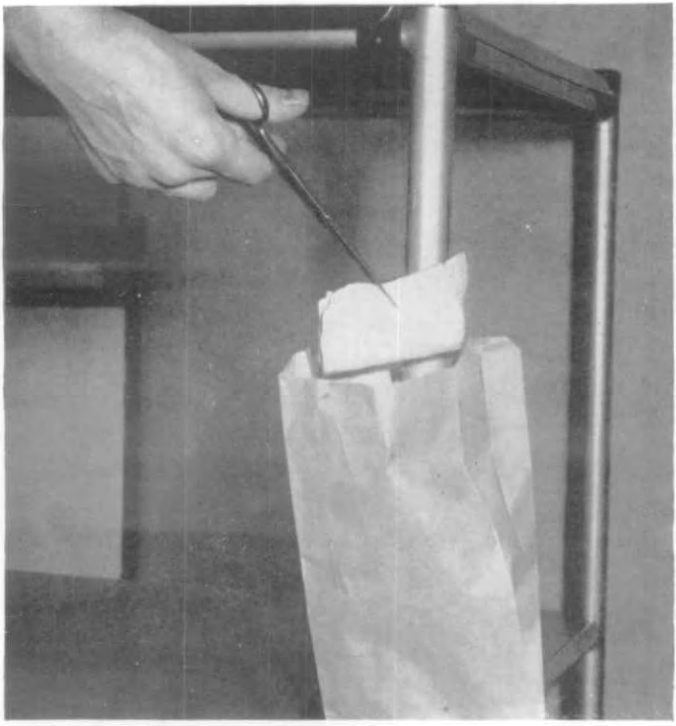
in some wards of Hospital A is more hygienic than the usual method of dropping the dirty dressings into an open bowl on the lower shelf of the dressing trolley, particularly if the bowls are filled up before being emptied. It is suggested that paper bags should be more widely used. As well as being a more hygienic method of disposal, the dirty dressing bins are less likely to become contaminated. A trade description of the right kind of bag to use is at Appendix F and photographs of how these bags may be used are shown opposite.

63. It is highly undesirable that, as shown in the photograph facing page 32, nurses or orderlies should have to sluice and count piles of dirty linen in the wards. Some hospitals have got over these difficulties by arranging for dirty linen to be removed from the ward as quickly as possible and dealt with in a central room. Here it is sluiced if necessary, sorted and counted by orderlies suitably dressed in protective clothing. If such an arrangement cannot be made at once nurses and orderlies should, at least, be provided with protective clothing as an interim measure.

64. One of the most unsatisfactory things noticed during the survey was the inefficient cleaning of bedpans by the bedpan washers. None of them was fully automatic and many were misused by the nursing staff. Sometimes hot water was used before cold, or a bedpan partly washed by one nurse would be left in the washer and taken out later by another. The bedpan washers proved so inefficient that as the investigation progressed it became clear that the only sure way to clean a bedpan properly was to do it by hand. This is an unsatisfactory state of affairs. Work is continuing on the better design of bedpans and bedpan washers, but until it has been completed no constructive suggestions can be made about the improved cleanliness of bedpans other than that they should be cleaned manually and protective clothing worn while doing so.

(f) Responsibility

65. LASTLY, AND PERHAPS THE MOST IMPORTANT OF THE POINTS MADE, IS THE NEED TO DEFINE RESPONSIBILITY. IN ONE HOSPITAL NOBODY ACCEPTED RESPONSIBILITY FOR SUPERVISING THE AUTOCLAVE ATTENDANTS, AND IN MOST OF THE HOSPITALS THE AUTOCLAVE ATTENDANTS DID NOT KNOW TO WHOM THEY WERE RESPONSIBLE. SIMILARLY IN HOSPITAL E NO ONE WAS MADE CLEARLY



Hygienic methods for disposing of contaminated dressings

[facing p 50

RESPONSIBLE FOR RELINING THE DRESSINGS BINS, OR FOR SEEING THAT IT WAS DONE. IT SHOULD BE CLEAR WHO IS TO DO ROUTINE TASKS, AND WHO IS TO SEE THAT THEY ARE DONE. ROUTINE PROCEDURES ARE MEANINGLESS UNLESS THEIR RULES ARE OBEYED AND ENFORCED. RESPONSIBILITY FOR CARRYING OUT ROUTINE STERILIZING TASKS AND RESPONSIBILITY FOR THEIR SUPERVISION MUST BE CLEARLY DEFINED, CLEARLY UNDERSTOOD AND UNDIVIDED. THE ONUS IS ON EVERY HOSPITAL AUTHORITY TO DEFINE THESE RESPONSIBILITIES AND TO SEE THAT THEY ARE ACCEPTED.

VI

Postscript

SINCE this report was written the two senior members of the investigating team have had an opportunity of visiting a number of hospitals in Switzerland, Germany, Denmark, Sweden and Finland to study their sterilizing practices. Since the visits were made primarily to hospitals which were thought to have good sterilizing practice and since inevitably these were the newer ones, some contrast with typical British practice was to be expected. The continental hospitals had more space, more terrazzo, more chromium plate, more stainless steel and more glass than is seen in British hospitals; and generally the sterilizing procedures were better. But this was not universally so; and, in spite of the better conditions, poor practices were seen as well as good. It was clear that the better facilities in the continental hospitals made proper sterilizing procedures easier. But they did no more than that. This experience has confirmed the view that what matters is the attention given to detail and the way the procedures are applied. As always, the human element decides the quality of the service given.

APPENDIX A

METHOD USED FOR TESTING THE AUTOCLAVES

THIS Appendix outlines the methods used for testing the autoclaves covered by this report. It is suggested that it should act as a guide to bacteriologists wishing to carry out a 'full-dress' test of their autoclaves. In this connection it should, however, be remembered that, if spore preparations are used, they must be of known thermal resistance. *Bacillus stearothermophilus* is a satisfactory test organism, but it requires careful and experienced preparation. The limitations regarding the use of spores are fully described by Kelsey (1958).*

Materials

The following materials were used:—

(*a*) a temperature recorder using thermistors (Messrs. Standard Telephones and Cables Limited);
(*b*) Browne's sterilizer control tubes, types I and II;
(*c*) dried spore suspensions of *Bacillus stearothermophilus* and a *Bacillus subtilis* type organism;
(*d*) a dressing drum approximately 12 inches diameter and 10 inches deep lined with two layers of butter muslin and packed with 18 dressing towels, each folded 2 × 2 × 3, so as to give 12 thicknesses of material.

'Stantel' type F thermistors, which can usually be bought from any ordinary electrical supplier, were used (Alder and Gillespie, 1957).† They are suitable for remote temperature indication because of their high electrical resistance. The recording instrument is easy to assemble, it is small and portable and has an accuracy within one degree centigrade. The whole equipment should not cost much more than £10.

The wire leads of the thermistors were soldered to the main insulated leads. The soldered joints were carefully insulated from steam and condensation. One method of doing this is to wrap each joint separately with glass fibre thread and then embed them together in 'Bakelite' polyester resin S.R. 17451 or Araldite,

* Kelsey, J. C. (1958). Lancet, **i**, 306.
† Alder, V. G., and Gillespie, W. A. (1957). J. clin. Path., **10**, 299.

using a mould of shaped polyvinyl tubing. Polymerization of the resin was effected by heating at 45 degrees centigrade overnight.* The thermistor and wire leads with insulated joints can be obtained already assembled from Messrs. Standard Telephones and Cables Limited.

The thermistors were calibrated by completely immersing them in hot oil in a thermos flask and plotting meter readings against a mercury centigrade thermometer on semi-logarithmic paper.

Two different kinds of Browne's tubes and spore cultures were used to make the assessment quantitative.

Browne's tubes Type I (black spot) and Type II (yellow spot) were used. Table IV below shows the time temperature values for a complete colour change.

TABLE IV. *Browne's Tubes*

Temperature °C.	*Time taken for complete colour change (mins.)*	
	Type I Black Spot	*Type II Yellow Spot*
126	9	5
120	16	9
115	25	15

Dried suspensions of *Bacillus stearothermophilus* spores and a *Bacillus subtilis* type spore were used.

The organisms showed the following experimental heat resistance.

Bacillus stearothermophilus spores. Over a number of tests in saturated steam the organisms survived for three to five minutes at 126° C. but were killed in ten minutes, they survived for five to ten minutes at 121° C. but were killed in 20 minutes, and survived for 20 minutes at 115° C.

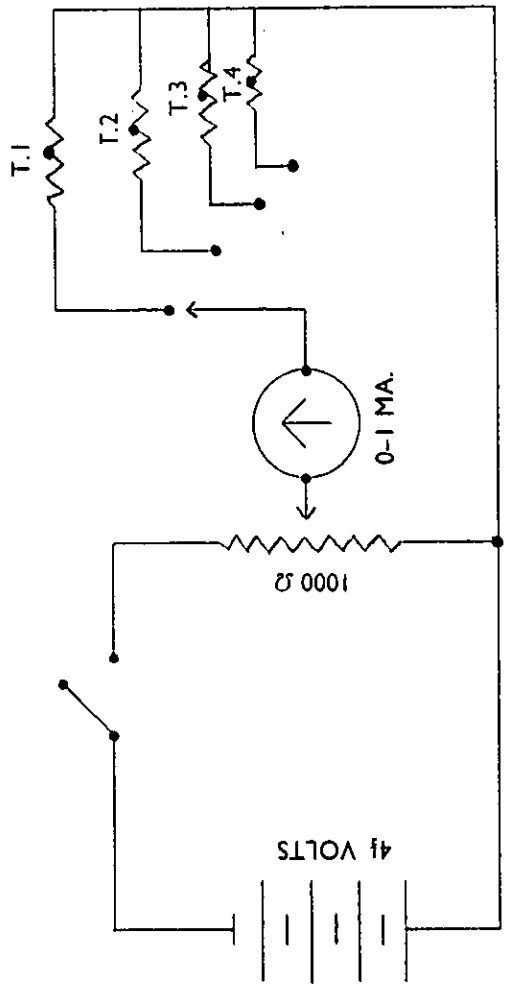
Bacillus subtilis type sporing organism. Kindly supplied by Dr. Kelsey, survived in saturated steam for 30 minutes at 100° C. but was killed in 60 minutes, survived for two minutes at 110° C. but was killed in five minutes.

The packing of the drum was firmer than one would recommend for routine practice so as to allow for the occasional overpacked container.

* Darling, G. H., to Alder, V. G. Personal communication.

THERMISTOR TEMPERATURE RECORDER CIRCUIT DIAGRAM

COMPONENTS



4. TYPE F/1512/300 THERMISTORS (STANTEL)
1. 1000 Ω HELIPOT. WIRE WOUND
1. 4 WAY SWITCH
1. ON OFF WAFER SWITCH
1. 0-1 MILLIAMETER
1. 4½ VOLT DRY BATTERY

DIAGRAM 4

Methods Employed

A thermistor was wrapped in one of the towels and placed in the centre of the drum.

Browne's control tubes Types I and II and cultures of *Bacillus stearothermophilus* and *Bacillus subtilis* were wrapped in the towels and inserted in the middle of the drum and on each side midway from the centre.

The drum was placed at the bottom of the autoclave chamber with the towel's folds vertical.

The positive wire leading to the thermistor was jammed between the autoclave door and the gasket, the wire being protected by a layer of adhesive tape. The negative wire from the thermistor was clipped to a metal projection inside the autoclave chamber. The circuit was completed by attaching another wire from the outside of the autoclave to the recorder.

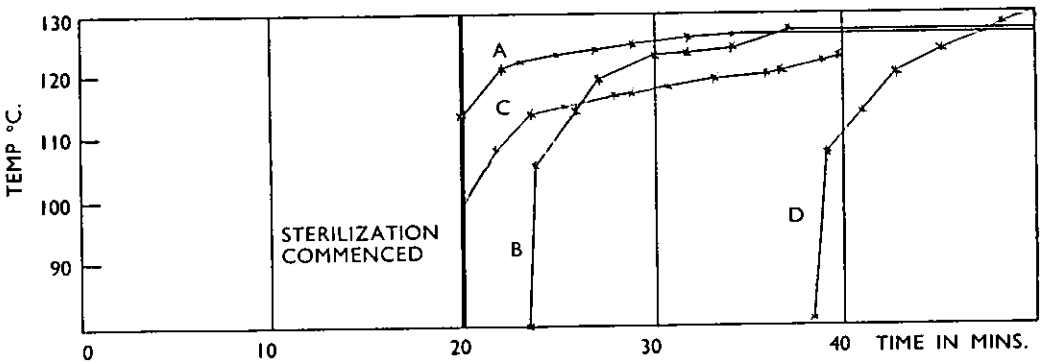
The circuit diagram is shown on p. 55.

Readings Taken

During the sterilizing procedure temperatures achieved inside the drum and pressures inside the chamber were recorded at approximately minute intervals, the course of events being timed by a stop-watch. Steam temperature at the chamber-drain outlet was checked when the apparatus was fitted with a thermometer and sometimes by a spare thermistor in the outlet pipe.

Assessment was made by plotting a time-temperature curve of the temperatures achieved inside the test drum and comparing this with the pressure curve and the temperature equivalent of the steam pressure. From this could be assessed the rate of penetration of steam to the centre of the drum, and delays caused by inefficient air removal. Overleaf is a diagram showing four different time-temperature curves which were secured as a result of actual tests made on different autoclaves working at a pressure of 20 lb. per square inch.

Curve A shows the standard demanded for a satisfactory result. The sterilization was carried out following a double evacuation of 20 inches Hg. The penetration time (i.e. the time taken for the centre of the drum to achieve maximum temperature) was 12 minutes. So that in an exposure time of 30 minutes at 20 lb. pressure per square inch of steam this would allow a holding time of 10 minutes and a safety period of eight minutes. The



	CURVE 'A' (SATISFACTORY)	CURVE 'B' (SATISFACTORY BUT SAFETY MARGIN REDUCED)	CURVE 'C' (UNSATISFACTORY)	CURVE 'D' (UNSATISFACTORY)
SCHEDULED STERILIZING TIME	30 MINS.	20 MINS.	20 MINS.	30 MINS.
3 BROWNE'S TUBES TYPE 1. BLACK SPOT	GREEN	GREEN	BROWN	BROWN
3 BROWNE'S TUBES TYPE 2. YELLOW SPOT	GREEN	GREEN	2 BROWN 1 GREEN	GREEN
3 *B. STEAROTHERMOPHILUS* DRIED SPORE SUSPENSIONS	KILLED	KILLED	SURVIVED	SURVIVED
3 *B. SUBTILIS* DRIED SPORE SUSPENSIONS	KILLED	KILLED	1 SURVIVED	KILLED

DIAGRAM 5

[*facing p.* 57

penetration time must be considered along with two other factors: i.e. a large capacity autoclave will take a few minutes longer than a small one; and the number of packages in the load must be considered. Twelve minutes is, however, adequate even for a large capacity autoclave.

Curve B shows a less satisfactory result because of a reduced margin of safety. In this instance there was evidence of an unsatisfactory steam supply to the chamber.

Curve C shows an unsatisfactory result because the curve is prolonged and does not reach the maximum; in this particular instance the chamber drain was not being used and there were other faults due to bad operation.

Curve D shows another unsatisfactory result primarily due to a faulty steam supply but bad design and bad operation were also factors.

The examination of air and condensate discharge pipes and air filters were made according to the recommendations of Howie and Timbury (1956)* and Scott (1957).†

Final Assessment

The final assessment of whether the autoclave was functioning satisfactorily or not was made by studying the evidence of the time-temperature curves along with the results of the spore cultures.

Culture Methods

Preparation of a spore suspension of Bacillus stearothermophilus. Two millilitres of a spore suspension of *Bacillus stearothermophilus* were heated in an oil bath for 10 minutes at 115° C. and immediately cooled.

The heated suspension was then added to about eight millilitres of dextrose tryptone broth containing brom-cresol-purple indicator and incubated at 60° C. overnight when growth showed turbidity and acid production. The culture was centrifuged at 3,000 revolutions per minute for 30 minutes and re-suspended in five millilitres of sterile tap water.

The sterile tap water suspension of the organism was flooded over the surface of about 50 millilitres of tryptone lemco agar which had solidified on the welled side of a 250 millilitre Roux flask lightly plugged with cotton wool. The Roux flask was

* Howie, J. W., and Timbury, M. C. (1956). *Lancet*, 2, 669.
† Scott, A. C. (1957). *Lancet*, 2, 633.

placed in a 60° C. incubator for seven days with the agar layer uppermost. Drying of the agar was prevented by adding a little sterile distilled water every other day to the lower part of the flask.

After seven days' incubation the growth was checked microscopically for spore production and washed off with 50 millilitres of sterile tap water, filtrated through a layer of sterile non-absorbent cotton wool into a narrow-capped bottle containing glass beads and thoroughly shaken for at least five minutes to break up clumps of spores. It was then heated in a boiling water bath for 15 minutes. This constituted the spore suspension.

The spore suspension was counted by the method of Miles and Misra* on dextrose tryptone agar. A satisfactory spore crop count showed at least 600,000 spores per millilitre.

Five drops (approximately 0·1 millilitre) of spore suspension were placed in the bottom of 2 × $\frac{3}{8}$-inch test tubes and dried for three days over $CaCl_2$ in a vacuum desiccator. The tubes were then lightly plugged and stored at room temperature in the dark.

Preparation of a spore suspension of Bacillus subtilis. The culture was spread over the surface of a blood agar plate and incubated at 37° C. overnight. The spore crop was harvested from the surface of the agar after it had been standing at room temperature for four to five days.

Tests for survival

Bacillus stearothermophilus spores. The deposits in the tubes were re-suspended in four drops of sterile distilled water and allowed to stand on the bench for 30 minutes and then thoroughly shaken. One drop was placed on the surface of dextrose tryptone agar in a petri dish, previously dried for one hour in a 37° C. incubator. Approximately one millilitre of dextrose tryptone broth was added to the remaining fluid left in the tubes. The plate was incubated for 24 hours at 60° C., the tubes were incubated for at least 48 hours at the same temperature.

Usually a slightly higher proportion of positive results was obtained from the agar plate than from the broth. This was probably because this organism required an abundance of oxygen during growth, and spores germinate better when exposed to air on the surface of agar media.

Culture Media. Annex A1 overleaf describes the culture media for *Bacillus stearothermophilus* spores.

* Miles, A. A., and Misra, S. S. (1938). *J. Hyg. Cambs.*, 38, 732.

ANNEX I TO APPENDIX A

CULTURE MEDIA FOR *BACILLUS STEAROTHERMOPHILUS*

Dextrose Tryptone Broth

Bacto tryptone	10 grams
Dextrose	5 grams
Soluble starch	1 gram
Water	1 litre

Dissolve, filter and adjust to pH 7·0.
Add 0·04 grams of brom-cresol-purple.
Sterilize for 20 minutes at 15 lb. pressure.
See also 'OXOID'. C.M. 73.

Dextrose Tryptone Agar

Bacto tryptone	10 grams
Dextrose	5 grams
Soluble starch	1 gram
Agar	15 grams
Water	1 litre

Dissolve, filter and adjust to pH 7·0.
Add 0·04 grams of brom-cresol-purple.
Sterilize for 20 minutes at 15 lb. pressure.
See also 'OXOID'. C.M. 75.

Tryptone Lemco Agar (for spore crop)

Lab lemco	3 grams
Bacto tryptone	10 grams
Agar	25 grams
Water	1 litre

Add lemco and tryptone to water, dissolve, filter and adjust to pH 7·0.
Dissolve agar in the broth.
Sterilize for 20 minutes at 15 lb. pressure.

APPENDIX B

SUPERVISION AND CONTROL OF AUTOCLAVE STERILIZING EFFICIENCY

APPENDIX A outlines the 'full-dress' test which it is suggested should be undertaken annually. Appendix B gives details of the further routine checks required to ensure that nothing can go wrong with the autoclaves without its being instantly noticed.

Checks of three kinds are suggested:—

(*a*) monthly by the pathologist or bacteriologist, to show that sterilization is being effective at the centre of a dressings container;
(*b*) daily by the supervisor, to show that the autoclave is working well and being operated properly;
(*c*) by the nurse, to ensure that none of her containers escapes the sterilizing process.

(*a*) *Bacteriologist's Monthly Test.* It is suggested that a test package be prepared containing spore cultures of known thermal resistance, as well as chemical indicator tubes. (See Appendix A with regard to the preparation of spore cultures.) These should be placed at the centre of the dressings container. The test package might then be placed at the bottom and front of the autoclave chamber and sterilized with a full load of dressings. The results of the spore cultures together with a study of the chemical indicator tubes and the control charts should provide sufficient information that sterilization is being effective at the centre of the dressings container.

It is also suggested that this monthly test might provide an opportunity for checking that dressings are not recontaminated during the drying process. The air inlet filter might then be inspected and clean swabs placed on the **outsides** of some of the packs or drums prior to autoclaving.

In interpreting the results of the tests the following remarks may be of assistance:—

(i) Pressure records alone can be misleading. The pressure could be due to a mixture of air and steam, and they give no indication at all of the efficiency of the chamber drain which is the most important part of the autoclave.

(ii) The most satisfactory check on the efficiency of the autoclave is a record of the temperatures at the drain outlet pipe from the base of the chamber. The timing of the sterilizing cycle is clearly indicated from the moment maximum temperature is reached. With sterilizers operated by an initial vacuum process, a dual record of both pressure and temperature is probably better and is an additional check that the method is being properly carried out.

(iii) Browne's tubes have been found to be satisfactory by several workers (Howie and Timbury, 1956; Scott, 1957; Alder and Gillespie, 1957; Kelsey, 1958). They do not discriminate between wet and dry heat, but if the colour changes are interpreted with care they provide a useful and reliable control. The maker's instructions about storage should be strictly adhered to. The indicator tubes must be put in the middle of the dressings container to give a true indication of sterilizing efficiency.

(*b*) *Supervisor's Daily Check.* It is suggested that this should be carried out on lines similar to those proposed for the bacteriologist's monthly check, except that spore cultures should not be used.

(*c*) *By the nurse.* Good administration should ensure that packages and drums are not left out of the autoclave in error. But an additional check can be made by placing an indicator on top of the dressings in every container so that it can be seen as soon as the lid is opened. An indicator of low sensitivity is needed which will change in the presence of steam but not in hot air; it should be cheap and should show clearly whether or not the dressings have been autoclaved. It is not intended to indicate sterility. One satisfactory indicator is the 'KLINTEX' paper manufactured by Robert Whitelaw (Newcastle) Limited, Klintex House, 44 Great North Road, Newcastle-upon-Tyne, 2. This is a paper strip, purple in colour with black lettering. In the presence of steam, the purple colouring disappears so that the black lettering 'AUTOCLAVED' is visible against a white background. Another cheap indicator which can be used is a cellophane wrapped tablet containing lactose 75 per cent., starch 24 per cent. and magnesium trisilicate one per cent.* The tablets turn brown during the autoclaving process.

* Darling, G. H., to Alder, V. G. Personal communication.

They can be supplied already enclosed in cellophane sheets by British Chemotheutic Products Limited, Kemtheutic House, Bradford, Yorkshire.

If wards and departments feel that they require some further indication then they might like to insert a Browne's indicator tube in some of their packages from time to time. They should keep a record of the results for the information of the medical staff. If the results should be in any way doubtful they should at once notify the supervisor.

APPENDIX C

TESTS APPLIED TO CARDBOARD BOXES

General Description of Manufacturing Methods

A BRIEF summary of the manufacturing methods may be of interest.

The cardboard is theoretically described as 'chipboard'. It is made from waste material such as old paper and cardboard. This is first pulped in water to a fine mash, coarse particles being filtered out and re-pulped. The mash has mixed in with it aluminium sulphate, a mixture of soda and resin, whilst chlorine gas is also injected into the mixture at a strength of not less than five parts per million. The process is automatically controlled and thorough mixing is ensured. The cardboard is then formed first by simple straining through wire mesh and canvas. Later the cardboard is formed on rollers. These are heated by steam to a pressure of 30 lb. per square inch. This process reduces the water content of the cardboard from the 65 per cent. at which it starts to about six per cent. The resulting board, which is two-ply, is then bonded together by an adhesive made from sodium silicate.

Laboratory Tests

The boxes were subjected to the following tests:—

Test No. 1. The speed and uniformity of steam penetration.
Test No. 2. Bacteriological and chemical indicator tests of sterilizing efficiency.
Test No. 3. Protection from bacterial contamination given to the dressings by the cardboard, under conditions of storage in a humid environment.
Test No. 4. Protection from dust-borne bacterial contamination.
Test No. 5. Tests for anaerobic sporing organisms.
Test No. 6. The effect of autoclaving the cardboard.

Test No. 1. To assess the rate of steam penetration into a packed cardboard box.

Method. A 10 × 10 × 6-inch cardboard box was packed to capacity with 10 huckaback towels; a similar number of towels was

placed inside a dressing drum lined with two layers of butter muslin; the same number of towels was also wrapped in two layers of butter muslin only. The packages contained thermistors at their centres for recording temperatures.

Results. Sterilizing temperatures were quickly achieved in the centre of the box with the towels, the speed of penetration was slightly quicker than that obtained in the centre of the towels inside the drum, but not as quick as that obtained inside the muslin wrapped pack.

In a separate experiment, thermistors were placed at the top, middle and bottom of a packed cardboard box. The box was placed on its side with the folds of the towels horizontal. The steam penetrated the carton evenly from the top downwards.

Test No. 2. Bacteriological and chemical indicator tests of sterilizing efficiency

Method. Twelve boxes were packed to capacity with towels. Dried spore culture of *Bacillus stearothermophilus* and Browne's indicator tube, black spot Type I, were inserted in the middle of each box.

The boxes, distributed in various parts of the chamber after double evacuation at 20 inches Hg, were autoclaved along with other goods in a large capacity (60 cubic feet) autoclave for 30 minutes at 20 lb. per square inch. This was done three times making 36 individual tests in all.

Results. Tests from all the boxes showed that the cultures were sterile on every occasion, and that the Browne's tubes showed a complete colour change.

In separate experiments in which sterilization was carried out for only 15 minutes (marginal conditions) satisfactory results inside the packed boxes were again obtained.

Test No. 3. Protection from bacterial contamination given to the dressings by the cardboard, under conditions of storage in a humid environment

Tests for the ability of the carton to protect the dressings from contamination during storage were made by heavily contaminating the outside of the box, previously moistened, with cultures of the

more common organisms found in wound sepsis, and then storing the box in a humid environment.

Method. A small box 11 × 5 × 1½-inches was completely packed with small pieces of gauze and sterilized by steam. The outside of the box was moistened with sterile water and then smeared with a thick suspension of *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas pyocyanea*. (The cultures were prepared by centrifuging overnight broth cultures of the organisms and resuspending the culture in about a tenth of the original broth volume. The *Staphylococcus aureus* was of a known phage type and the *Escherichia coli* had a known colicene pattern so that these organisms could have been recognized had they penetrated the cardboard.)

The box was stored in a polythene bag containing a small quantity of water, to maintain humid conditions, and kept at room temperature for three months—8th May 1958 to 30th July 1958.

Tests were made by swabbing the inside and outside of the box at intervals.

The swabs were rubbed over the surface of nutrient agar plates and incubated aerobically for four days at 37° C.

Pieces of gauze were taken out and placed in broth and incubated aerobically for 7 days.

Finally, portions of the cardboard were cut into 12 ½-inch square pieces, placed in nutrient broth and incubated for seven days at 37° C.

Results. The outside of the box. After 24 hours a profuse growth of all three test organisms was obtained. After three days none of the Gram-negative organisms could be recovered and the *Staphylococcus aureus* was considerably reduced in numbers.

Swabbing at six days' storage yielded a scanty growth of *Staphylococcus aureus* only.

Swabbing at fortnightly intervals up to three months showed that none of the original organisms remained. A scanty growth of an aerobic Gram-positive sporing bacillus was obtained, presumably an air contaminant, some diphtheroid organisms and on one occasion very scanty (one or two colonies) of *Staphylococcus aureus*.

The inside of the box. The inside of the box remained sterile for the three months' period of observation.

The cardboard portions. Eleven of the 12 pieces of cardboard

cut from the box lid after three months' storage under the conditions described, were sterile. The other portion yielded a growth of a Gram-positive aerobic sporing bacillus.

The Gauze. The test pieces of gauze remained sterile throughout the three months' storage period.

Test No. 4. Protection from dust-borne Bacterial contamination

Method. Two cardboard boxes were sterilized by autoclaving.

Box A was the improved pattern described in Appendix D of this report.

Box B was an average box selected from the factory. It had pin-hole gaps in the corners.

An open plate of Wort agar was put inside each box.

The boxes were placed inside a 27° C. incubator which contained a circulating fan; an open plate of Wort agar was left exposed to the incubator atmosphere. A sporing culture of a non-pathogenic mould was placed over the outlet of the fan to create conditions of heavy air-borne contamination. A mould was chosen because it was a convenient test organism and easy to grow, and the spores in the atmosphere corresponded to the condition of air-borne contamination by other micro-organisms.

At the end of 36 hours' incubation, the open plate exposed to the incubator atmosphere was evenly covered with a heavy growth of mould.

At the end of six days' incubation, the plates inside the boxes were examined and only a very small number of mould colonies were present, four colonies were counted on the plate from Box A (protected corners), 12 colonies on the plate from Box B.

A similar test was also carried out by leaving the boxes (A and B) under an open window for six days where there was a good current of air. The plate from Box A (protected corners) showed one colony growing at the end of six days, while the plate in Box B showed eight colonies of a mixed growth of moulds.

Results. The cardboard boxes are well able to protect their contents from atmospheric contamination. The test which was carried out in a closed incubator was very severe, more so than one would be likely to meet in ordinary working conditions, but only a small number of spores were able to penetrate the boxes.

In more normal atmospheric conditions of storage the box with the protected corners gave better protection to the contents from outside contamination.

Test No. 5. Tests for anaerobic sporing organisms

Method. Portions of new cardboard were cut into very small pieces and mixed together. 1 gram, 0·2 gram and 0·1 gram of cardboard was added to 20 millilitres of boiled Robertson's meat medium.

The mixture of board and medium was heated to 80° C. for 15 minutes to kill vegetative organisms and incubated for 48 hours at 37° C.

At the same time portions of cardboard were added to Dextrose Tryptone Broth, heated at 100° C. for 10 minutes and placed in the 60° C. incubator to grow thermophilic organisms.

From the Robertson's meat broth cultures, subcultures were made on to blood agar medium which was incubated anaerobically and aerobically.

Films were made from the cultures and examined microscopically.

Results. The results showed that the cardboard contained many varieties of anaerobic sporing bacilli, some of them morphologically resembling *Clostridium tetani.* The tetanomorphic organisms were present in 0·2 gram of the cardboard.

Thermophilic organisms were also present in 0·1 gram of the board.

Test No. 6. The effect of autoclaving the cardboard

Method. Sheets of cardboard were wrapped in six layers of butter muslin and autoclaved at 20 lb. pressure of steam for 30 minutes.

Small portions of the cardboard were added to Robertson's meat medium and dextrose-tryptone-broth as before and incubated for seven days.

Results. The results showed that the cardboard was sterile and that autoclaving the boxes sterilizes them satisfactorily.

(All these results were confirmed independently at the Central Pathological Laboratory, Portsmouth.)

Conclusions

THE cardboard boxes gave satisfactory indications of being very suitable containers for packing and storing surgical dressings. They showed a satisfactory level of sterilizing efficiency; steam penetration was rapid and even. Chemical indicator tests showed satisfactory results and spore cultures of *Bacillus stearothermophilus* were killed under marginal conditions of sterilization using cartons packed to capacity. A preliminary assessment of the use of cardboard cartons as containers for dressings showed that the steam sterilization efficiency of the cardboard cartons was better than a dressing drum but less efficient than a muslin-wrapped pack.

The results of the bacterial contamination tests show that the dressings were adequately protected and remained sterile for the three months' duration of the test. The specially designed corners of the box protect the dressings from dust better than the conventional type of drums and a lot better than most.

The cartons appear to possess some slight antibacterial property in the cardboard because the numbers of certain vegetative bacteria seem to be reduced more quickly than one would expect. This is probably because in the process of manufacturing the cardboard, antiseptic substances are incorporated.

The cardboard boxes are more suited to the vacuum type of sterilization than the downward displacement method. Recent tests with the new English type high speed, high-vacuum autoclaves gave satisfactory sterilization of the box contents. Finally, although the cardboard boxes may have collected anaerobic sporing organisms during manufacture it has been shown that these are destroyed by autoclaving. As stated in Appendix D, the manufacturers have undertaken to autoclave the boxes before putting them on the market.

APPENDIX D

DESIGN OF CARDBOARD BOXES

THE cardboard boxes used in the central sterile supply department of the Cambridge Military Hospital, Aldershot, had certain advantages over metal dressing drums as containers for sterile dressings. For example:—

(*a*) the boxes were cheap and disposable;
(*b*) the deep fitting lids of the boxes gave more protection against dust gaining access to the dressings than the lid and sliding metal bands of conventional drums;
(*c*) the shape of the boxes allowed easier stacking. They were light to handle, reasonably robust and could withstand 12 autoclavings before disintegrating.

But they were also not without some disadvantages:—

(*d*) they were covered with a paper which tended to peel off after about a dozen autoclavings;
(*e*) small holes were liable to occur at the corners of the box;
(*f*) they had to be stapled when being assembled.

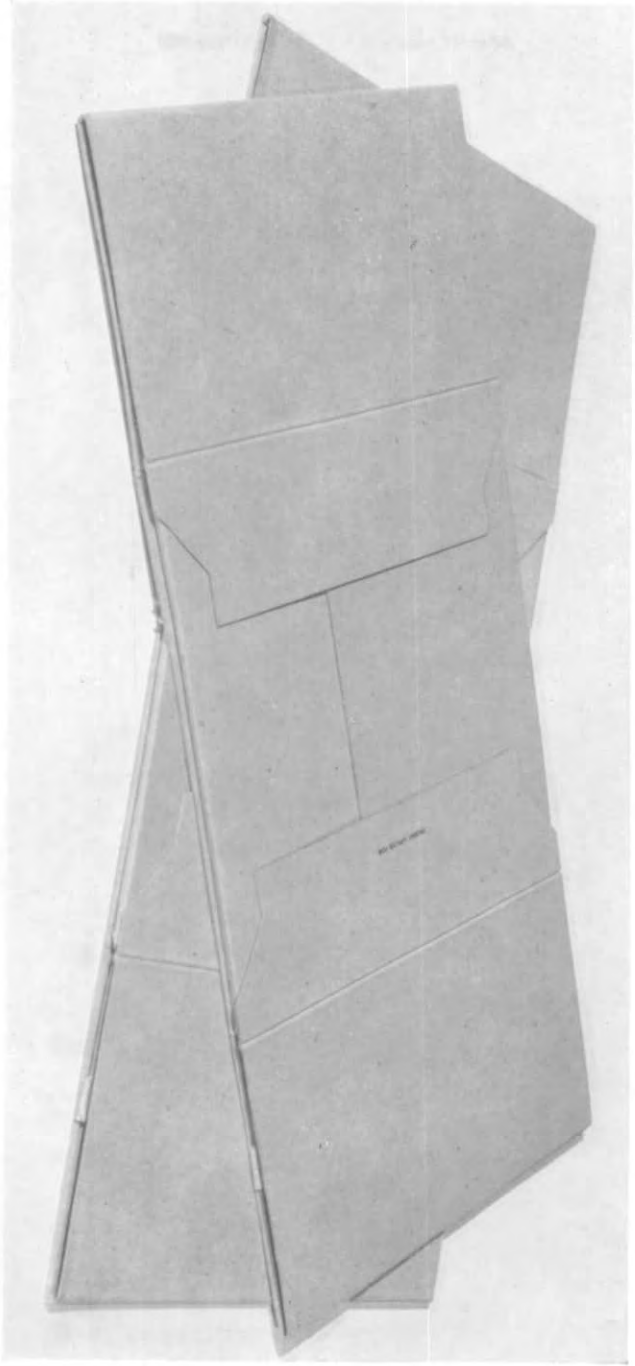
A firm of cardboard box manufacturers considered that they might be able to design a box without the disadvantages mentioned at (*d*) to (*f*) above. This they have done and the following improvements have been made:—

(*g*) the box and lid are both collapsible so that they can be stored easily but they are, at the same time, simple to erect in a few moments;
(*h*) a few staples only are needed and these are put in by the manufacturers before sale;
(*i*) in the process of erecting the box the corners are so designed as to form a tight seal against the access of dust.
(*j*) in an autoclave operated by a double 20 inch Hg partial vacuum the boxes have been found to withstand some 24 autoclavings before becoming mis-shapen.

These improvements are illustrated opposite and overleaf. Boxes to this design are now in production in three sizes, small, medium and large.

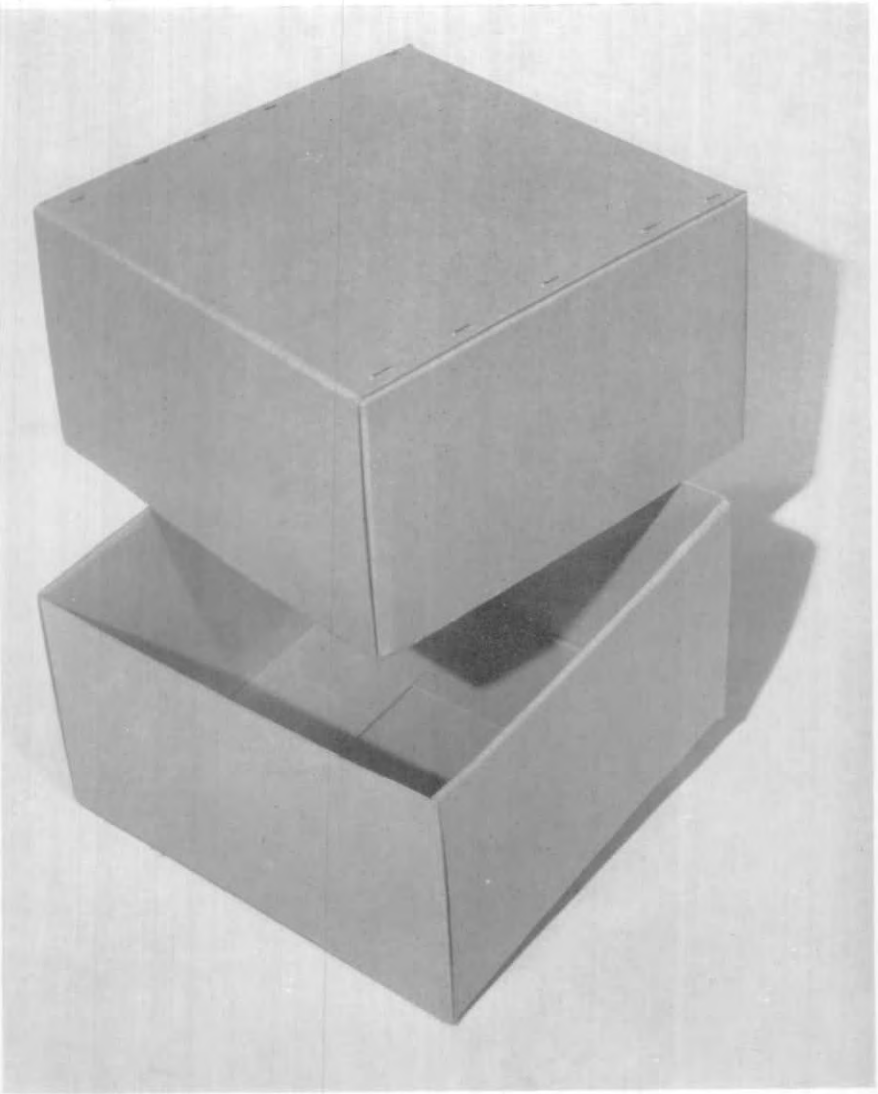
Before these boxes could be put on the market it was decided to test them for sterility. Tests No. 5 and No. 6 (see Appendix C) showed that they were heavily contaminated by many organisms probably during manufacture. These organisms were killed by ordinary autoclaving. The manufacturers of the boxes have, therefore, agreed to autoclave their boxes before sale. This should ensure that the boxes cannot be a source of contamination in hospitals.

The manufacturers have applied for a patent for the boxes and they can now be bought under the trade name 'Bripac' through the usual commercial representatives visiting hospitals.



A cardboard box before assembly

[*facing p. 72*



A cardboard box after assembly

[facing p. 73

APPENDIX E

STERILIZATION OF SYRINGES

IF there is no central syringe service or hot-air oven available, then syringes may be packaged and sterilized in the autoclave along with the dressings.

After use the syringe and needle should be washed in soapy water, well rinsed and, as far as possible, dried before they are packed. Since hospital autoclaves vary, two different methods of packing may be required:—

(*a*) *Where the autoclave is only capable of drawing a pre-vacuum of up to* 20 *inches Hg or is operated by gravity displacement:*

Syringes should be packed **dismantled.** This is essential since steam under such conditions is unable to replace the air that would be trapped inside the assembled syringe.

It may be found convenient to put each plunger, barrel and needle in an unbleached calico bag, secured around the middle with tape. A small bag similar in design to that used for packing surgical gloves is suitable. Syringe packs, possibly in units of 12, can then be put into the type of cardboard box described in Appendix C and sent to the autoclave. Syringes must be loosely packed in the box so that steam may circulate freely inside it.

(*b*) *Where the autoclave is fitted with a pump capable of drawing a minimum pre-vacuum of* 29 *inches Hg.*

Under these conditions a syringe may be assembled before sterilization but it should not be lubricated. The high vacuum removes the air inside the syringe thereby allowing steam to penetrate and do its work.

In this case a different method of packing can be employed. For example, a glass or aluminium container may be used. It is, however, important that the container should not be sealed until **after** the syringe has been sterilized.

As each syringe is used once, and once only, before it is re-sterilized, it will be necessary to increase a ward's stock of syringes to not less than twice the average number of injections given daily. If the number of injections given differs greatly from day to day

then more will be required. Although the capital expenditure on additional syringes will be appreciable, it will be less than that of a full central service. No reduction in the amount of nurses' work with syringes can be expected. This may, if anything, be slightly increased.

APPENDIX F

PAPER BAGS

THE following trade description of paper bags suitable for the disposal of dirty dressings may assist hospitals wishing to order them.

Bags should be satchel-shaped with three-inch gussets, strung and made from DC/20-lb. wet strength M.G. Bleached Kraft paper. Some manufacturers may also be able to impregnate the paper with bacteriocidal agents during manufacture. This would be an advantage.

(The gussets enable the mouth of the bag to be as large as possible in order to facilitate the insertion of the dirty dressing. The wet strength gives the paper the added property of retaining a high proportion of its dry strength when wet, even to the point of saturation.)

The bags may be obtained in suitable sizes such as $5\frac{1}{2} \times 3 \times 9$ inches and $7 \times 3 \times 12$ inches from the usual commercial firms providing such equipment.