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Technological Problems of Vacuum-packed Sliced Cooked Ham.

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The development of sliced vacuum-packed ham for sale to the public involves the overcoming of a considerable bacteriological hazard, since the cooked meat provides an excellent medium for proliferation of many organisms, including pathogens.

In the United States, vacuum-packed ham is sold in large quantities without in-pack pasteurisation, since sufficient protection appears to be afforded by cooking and subsequent distribution under refrigeration, but in Britain the product may be stored at room temperature for one or two days before use by the consumer, and may also be stored in the shop under similar conditions. It is found that the product as produced in the U.S.A. for distribution under refrigeration would be bacteriologically unsafe under British distribution conditions at room temperature.

Two methods of progressing the technology of this product have been investigated, i.e.

(1) for distribution under refrigeration only.
Following U.S.A. practice but using special hygienic precautions to avoid human contact with the meat after cooking.

(2) for distribution with or without refrigeration.
A study of methods of in-pack pasteurisation.

The first stages of preparation of the ham are common to both inquiries and some experimental details are as follows.

The boned and defatted legs from heavy hogs of about 118 Kg. liveweight were cured by multi-needle injection of brine at the rate of 6½% by weight on two successive days, the needles being spaced at 2.54 cm. centres. After 2-4 days maturing the hams were vacuum drawn into rectangular moulds of 11.43 cm. x 11.43 cm. cross- section, compressed by spring pressure, cooked at various times and temperatures, averaging 3¾ hours at 75°C., and cooled in running water. Chemical analyses of the ham before and after cooking were as follows:

	NaCl %	$NaNO_2$ p.p.m.	Phosphate %
Before cooking	4.4	231	0.70
After cooking	3.5	82	0.67

The results are the average of six determinations.
At this stage samples of the ham showed counts in the order of only 100-300 organisms/g. and sometimes much lower.

Section (1) Experiments in Refrigerated Distribution.

Strict hygiene reduced subsequent contamination to a minimum. A series of simple tools of stainless steel was designed which enabled the operator to eject the ham from the mould and transfer it to the slicer without touching the meat. The slicer was of the American type which automatically deposits the slices in groups of 4, 6 or 8, either shingled or stacked, onto a plastic conveyor belt. Further simple tools were made which enabled operators to weigh, adjust weight and transfer the slices into pouches, again without human contact. The slicer and all tools and equipment were cleaned with quaternary ammonium compound four times daily.

The following table shows the counts obtained on such packs after storage at 4°C. for 8 or 9 days.

Table 1.

Bacterial counts on packaged ham after 8-9 days storage under refrigeration (4°C.)

Organisms per g.
100 (8 results)
200 (3 results)
300 (3 results)
600
4,500
4,900
1.5×10^5

While these results were considered satisfactory it was appreciated that in practice the packs would be purchased and taken to homes without refrigeration. A number of packs were therefore stored at 4°C. for periods of 8-11 days and subsequently kept at room temperature (circa. 18°C.) for three days.

Table 2.

Bacterial counts on packaged ham after refrigerated storage followed by storage at room temperature.

Storage conditions	Counts/g. after storage.
8 days at 4°C. then 3 days at 18°C.	3,800, 2,300, 77,600, 8,700 13,000, 1,000, 3.6×10^7, 3.3×10^6
9 " " " " " "	100, 16,000, 7,800, 500, 200 8,800, 8.04×10^6, 1.13×10^5
10 " " " " " "	5,100, 7.6×10^5, 4×10^5(2), 2.5×10^5 1.9×10^6, 4.4×10^6
11 " " " " " "	4.8×10^5, 2.87×10^5, 3.98×10^5

While most of these results are acceptable it was considered that some risk remained and a further improvement in technique was sought.

The techniques described above were designed to avoid direct contamination from operators and equipment, but no effort was made to control air-borne contamination. In order to ascertain if further refinement of techniques, such as the use of a sterile room for packing, would lead to substantially longer shelf life, sample packs were treated by irradiation, a dose of 10^5 rad being used.

Table 3.

Bacterial counts during storage of irradiated and control packs of ham.

Storage	Control Organisms/g.	Irradiated Organisms/g.
0 days room temperature	24	8
0 " " " "	17	3
0 " " " "	24	11
1 " " " "	35	8
1 " " " "	2×10^3	4
1 " " " "	8×10^3	8
4 " " " "	1.3×10^8	3.3×10^6
4 " " " "	9.1×10^7	3.5×10^6
4 " " " "	6.7×10^7	3.2×10^6
6 " " " "	1.9×10^8	7.7×10^7
6 " " " "	1.3×10^8	9.5×10^7
6 " " " "	2.6×10^8	8.2×10^7
8 " " " "	3.7×10^8	1.1×10^8
8 " " " "	4.8×10^8	2.0×10^7
8 " " " "	2.7×10^8	9.4×10^7

Thus although the original counts were reduced to very low figures no real improvement in shelf life was obtained as the counts on day 4 were unacceptable and the products inedible on day 6. The results demonstrate the extremely rapid growth of even a small number of surviving organisms on storage at room temperatures. Both vegetative and sporing organisms were found among the survivors in this experiment.

It was concluded from these series of experiments that the special hygienic precautions enabled one to distribute the ham under refrigeration provided that the packages were labelled "eat within 24 hours of purchase" and that the time under refrigeration was kept to less than ten days. This was a very limited achievement and attention was therefore directed to the possibility of in-pack pasteurisation.

Section (11) Distribution With or Without Refrigeration

Suitable heat treatment guarantees destruction of vegetative cells and also delays germination of surviving spores. The experiments described in Section 1 show that low counts are commercially feasible and these packs were made the starting point of a number of short time pasteurising treatments.

The pouches commercially available at the time these experiments were begun (1958-1959) were found to be unsuitable for immersion in hot water, considerable delamination being liable to occur. Thus our first efforts were directed towards a dry-heating process.

Air-heating was not feasible, due to the slow rate of heating found and consequent excessive fat and liquor throw-out. Some interesting results were obtained using a heating bath of a commercially available alloy of tin, lead, cadmium and bismuth, melting at 68°C. This medium was expected to provide the best possible availability of heat to the pack and thus the fastest rate of heating. In addition it was expected that the weight of metal pressing on the sides of the pack would be enough to expel all air, and would thus permit sealing of the pouch just above the surface of the metal and elimination of the vacuum sealing stage of the process. Studies of heat penetration (graphs 1-3) showed that an internal temperature of 70°C. was reached more quickly than when water was used as a heating medium. The method was not pursued beyond the laboratory stage, however, as various extraneous problems arose, such as contamination of the metal by traces of fat on the outside of the pouches with consequent loss of metal by adhesion to the pouch.

With the development of improved pouches, able to withstand heating in water at 85-90°C, water pasteurisation became feasible. From the heat penetration graphs it can be seen that 3¼ minutes heating in a water bath at 85°C. is required to raise the temperature of the pack to 70°C. In order to minimise overcooking of the ham, experiments were carried out using processes little greater than this minimum, but results were not as satisfactory as expected, for example

Pasteurisation treatment	Storage conditions	Total count after storage. Org/g.
5 minues in water at 88°C.	7 days room temp.	95,000, 102,000
4 " " " "	7 " " "	900, 750,000

In order to achieve stability it seems necessary to resort to higher temperatures and times than are desirable from the standpoint of product quality. A wide choice of pasteurisation treatments is possible and will depend upon the number and weight of slices per pack, initial bacteriological loading and many other factors. The following table illustrates the stability achieved when the product receives treatments of from 10-20 minutes in a bath at 85°C., i.e. up to four times the process indicated by the heat penetration data . Pouches were treated for various times and tested after 5, 12 and 17 days storage at room temperature.

Table 4.

Effect of various pasteurisation treatments on bacterial counts of packaged ham stored at room temperature.

Pasteurisation time	Counts per g after storage.		
	5 days	12 days	17 days.
0 minutes (control)	uncountable	10 million	6 million
5 "	48,000	27,000	2,400
10 "	3,000	2,000	1,200
15 "	2,400	300	1,200
20 "	600	10	200

The stability is presumably achieved by the heat attenuation of surviving spores combined with the inhibitory influences on spore germination of anaerobic conditions, smoke and the presence of curing salts.

Based on the results given above a commercial process has been developed which consistently gives a shelf life of 14 days. From the bacteriological standpoint a longer period would be possible but other factors intervene, notably loss of ham flavour after 14 days.

Over a three month period in which pouches were treated under factory conditions the range of bacterial counts, after 14 days storage at room temperature, was as follows:

Table 5.

Summary of bacterial counts on pasteurised packaged ham after 14 days storage at room temperature.

Organisms/g.	% of samples within range	
	Ham	Cured shoulder.
<100	84.8	74.8
<1,000	10.6	16.1
<10,000	2.6	7.2
>10,000	1.6	1.9

This table summarises the results of 300 observations. The maximum counts found were 500,000 and 108,000.

Strict hygiene is enforced in the slicing and bagging operations in order to leave the minimum number of organisms for treatment by in-pack pasteurisation. In practice, the following distribution of counts was obtained on the ham before pasteurisation.

Table 6.

Summary of bacterial counts in ham before pasteurisation.

Total count per g.	% of samples within range.
less than 100	32.4
100 - 1,000	46.2
1,000 - 10,000	18.8
10,000 - 100,000	2.6
greater than 100,000	-

These figures represent 231 samples taken over 3 months production.

It is desired to emphasise that the results reported in Table 4 apply only to ham of the chemical composition and microbiological loading indicated above. A few experiments have shown, for instance, that in-pack pasteurisation of uncured boiled pork gives a shelf life of less than seven days.

In April, 1960, 20 commercial pasteurised packs, ten of ham and ten of cured shoulder, were examined bacteriologically by the Food Hygiene Laboratory, Colindale (Hobbs, personal communication). These

were subjected to the following conditions:

(a) Examined on arrival.
(b) Incubation at 22°C., examined at 1, 2, 4 days.
(c) Incubation at 37°C., examined at 1, 2, 4 days.
(d) Storage for 5 days at 4°C., examination (i) immediately, and (ii) after 13 days at 22°C.

Counts were made on blood agar using the Miles and Misra (1938) surface technique; predominant organisms on blood agar, directly and after enrichment through cooked meat were noted. The samples were also examined for coliform bacilli and intestinal pathogens. Table 7 shows the results obtained.

Table 7

Test Conditions	No. of samples	Surface plate count per g. at 37°C.	PREDOMINANT ORGANISMS	
			Direct cultures	Enrichment cultures
Examined on arrival	4	<500	none	Aerobic sporing bacilli and micrococci
Incubated at 22°C. examined after (a) 1 day	2	<500	none	Aerobic sporing bacilli
(b) 2 days	2	<500	Slight growth of aerobic sporing bacilli (1 pack)	Aerobic sporing bacilli and micrococci.
(c) 4 days	2	<500, 10,000	" "	Aerobic sporing bacilli.
Incubated at 37°C. examined after (a) 1 day	2	< 500	none	Aerobic and anaerobic sporing bacilli.
(b) 2 days	2	< 500	none	Micrococci and non-haemolytic streptococci.
(c) 4 days	2	<500, 200,000	Profuse growth of aerobic sporing bacilli (1 pack)	Aerobic sporing bacilli.
Stored 5 days at 4°C. examined (a) immediately	2	< 500	none	Aerobic sporing bacilli
(b) after 13 days at 22°C.	2	350,000, 750,000	Moderate growth of aerobic sporing bacilli.	Aerobic sporing bacilli.

0.1 gram samples taken from each pack did not show the presence of coliform bacilli. Organisms of the salmonellae and dysentery groups or coagulase-positive staphylococci were not found.

SUMMARY

The problems of vacuum packed sliced cooked ham are discussed. Two possible approaches are outlined, namely:

(1) Reduction of bacterial numbers and avoidance of direct human contact by a refined production technique combined with refrigerated distribution.

(2) Inpack pasteurisation. Starting with low count material, <500/g. pasteurisation processes in the range 10-20 minutes immersion at 85°C. gave a stable product for 14 days at room temperature.

Acknowledgement. The author wishes to thank Dr. Hobbs for permission to reproduce the data relating to Table 7.

References

Hobbs B.C. 1960. Private communication.

Miles A.A. & Misra S.S. (1938) J. Hyg.(Lond)38.738.

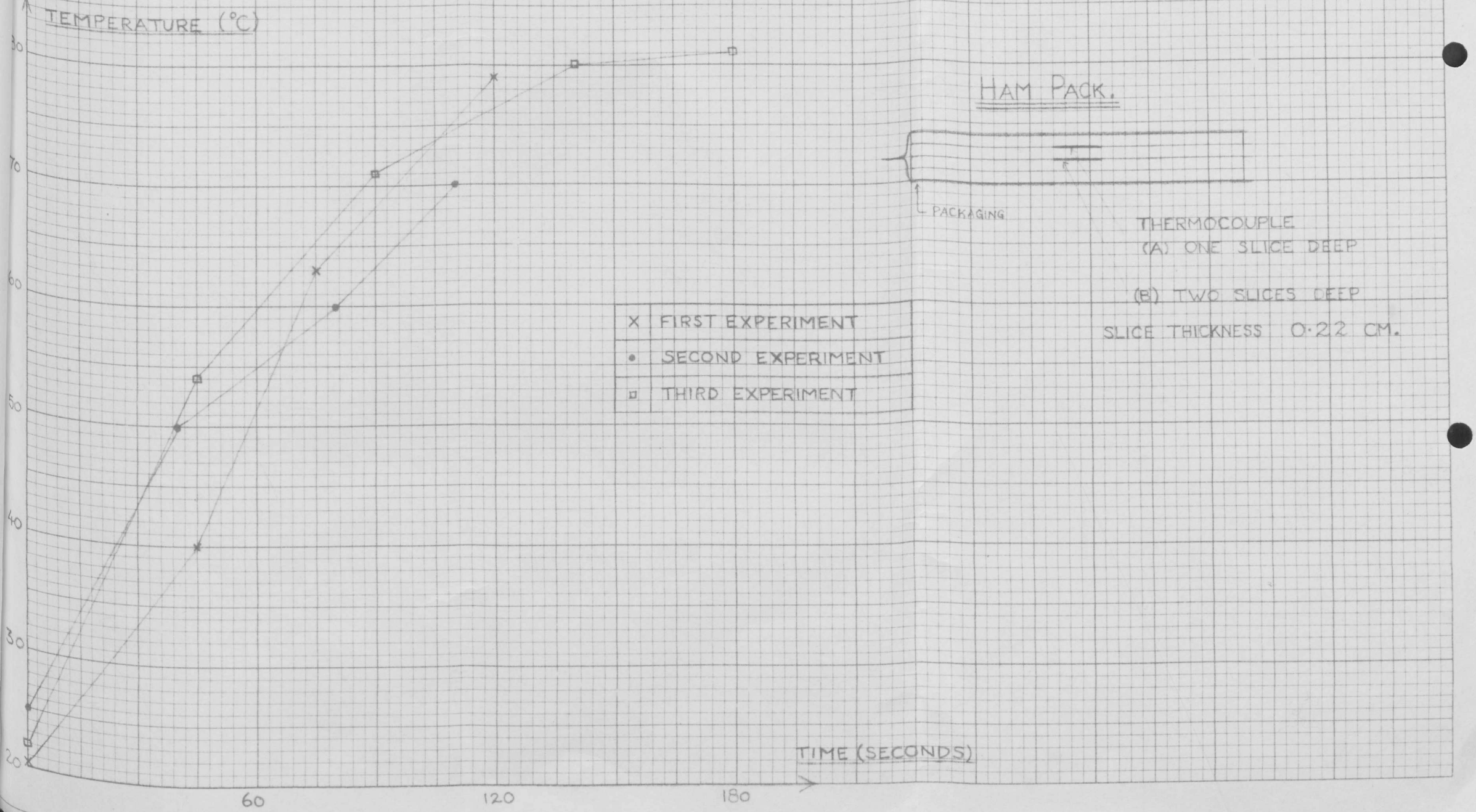
GRAPH 2.

HEAT PENETRATION INT

GRAPH 1.

HEAT PENETRATION INTO VACUUM-PACKED HAM HEATED IN WATER AT 85°C.

READINGS TAKEN ONE SLICE DEEP (0·22 CM DEEP)



X	FIRST EXPERIMENT
•	SECOND EXPERIMENT
□	THIRD EXPERIMENT

HAM PACK.

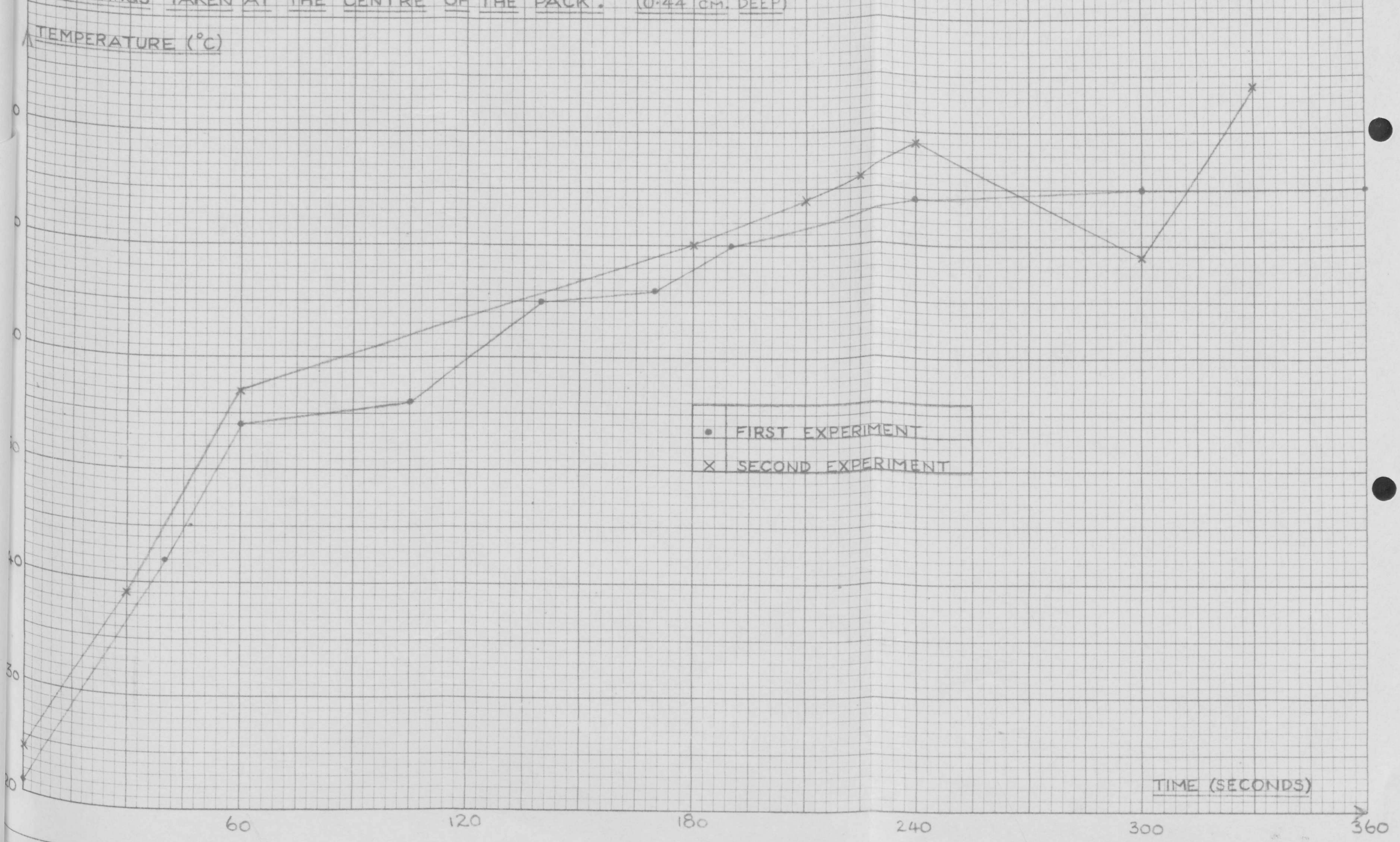
THERMOCOUPLE
(A) ONE SLICE DEEP
(B) TWO SLICES DEEP

SLICE THICKNESS 0·22 CM.

GRAPH 2.

HEAT PENETRATION INTO VACUUM-PACKED HAM HEATED IN WATER AT 85°C.

READINGS TAKEN AT THE CENTRE OF THE PACK. (0·44 CM. DEEP)



GRAPH 3.

HEAT PENETRATION INTO PACKED HAM IMMERSED IN MOLTEN METAL AT 90° - 94° C.

READINGS TAKEN AT ONE-SLICE (A) AND TWO-SLICE (B) DEPTHS IN THE FOUR-SLICE PACK.