Fire Research Note 610

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NO. 610

THE FIRE PROPERTIES OF COOKING FATS

by

G. W. V. STARK and WENDY MULLINER

November, 1965.

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SUMMARY

Tests on the fire properties of cooking fats used for deep frying have shown that when a cooking fat of any kind is overheated without food added, the spontaneous ignition temperature and the fire point are reached when the temperature is increased to about 310-360°C. There is, therefore, an immediate danger of fire at temperatures above about 310°C. There is also no substantial difference in the fire hazard of different fats, nor does the repeated use of the fat increase the fire hazard.

Liquid fat at cooking temperatures, (205°C) is unlikely to catch fire if the fat passes through a flame, but can ignite on surfaces at or above dull red heat. Such surfaces may be presented by solid electric plates and they are almost certain to be presented by radiant electric plates during cooking.

The substantial interval between the maximum cooking temperature and the temperature at which there is an imminent fire hazard, indicates that the presence of a suitable thermostatic control on cookers would greatly reduce the risk of dangerous overheating.

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Introduction

Fires in cooking appliances form a significant and increasing fraction of the total number of fires[1,2,3]. Thus the number of fires in buildings in the United Kingdom attended by fire brigades increased from 51,000 in 1955 to 79,000 in 1963 (i.e. just over $1\frac{1}{2}$ times). In the same time those fires on cooking appliances in which food was the material first ignited, increased from 3,000 to over 7,000 (2.3 times). In about 90 per cent of these fires the foods concerned were fats and oils. There is evidence that an important contributory factor to these fires is the ignition of fat and oil in a pan when it is left unattended. There is also evidence that the chance of a food or fat fire is greater with an electric cooker than with a gas cooker.

In an earlier investigation[4], the fire properties of one fat (ground nut oil) were studied and the conclusion was reached that a major fire hazard would result if the fat were overheated to a temperature of about 150°C in excess of the standard cooking temperature. A possible reason for the increase of fires in cooking appliances might be that a fat in common use could become especially hazardous under practical conditions. The main object of the enquiry described in this report was to look for any evidence that this might be so. A second object was to determine whether there were any differences in the incendive properties of gas and electric cookers which might contribute to the higher frequency of fires associated with electric cookers.

Experimental

Materials and apparatus used

Six fats were used in the tests as follows:-

Corn oil
Ground nut oil, and } representing vegetable fats
Olive oil

Lard and dripping - representing animal fats

A hydrogenated cooking fat marketed by a multiple grocers.

The ignition temperature and the smoke and flash points of the fresh fats are given in Table 1. The ignition temperature was measured in an apparatus, shown in Fig.4, similar to that of the Electrical Research Association following the standard procedure, and the smoke and flash points were measured using apparatus specified in B.S. 684 : 1958.

Table 1

	Ignition temperature E.R.A. Apparatus		Flash point		Smoke point	
	°C	°F	°C	°F	°C	°F
Corn Oil	414	778	245	473	219	427
Ground Nut Oil	409	768	242	468	224	436
Olive Oil	417	782	228	443	164	327
Lard	419	786	252	485	227	441
Dripping	420	788	238	460	154	309
Hydrogenated Cooking Fat	403	757	291	555	229	444

Three heating appliances were used. (Fig.1).

1. The burner of a (two burner and grill) gas hob.
2. A 2 KW solid hot plate, controlled by an energy regulator ("simmer stat").
3. A 2.2 KW radiant hot plate, 8 in dia., controlled by an energy regulator. ("simmer stat").

Thermocouples were fitted to these heating appliances to measure the temperature of the surfaces on which fat could be spilled. Gas flow was measured by a flowmeter. Energy input into the electric plates was not measured directly, but the switching cycle of an energy regulator was measured to determine the proportion of load passed for a given setting of the regulator. This was found to be affected by the time the regulator had been operating and by the direction in which the setting of the regulator was altered. (Fig.2).

The solid electric plate was controlled accurately by a special system for measurements of the temperature of the plate at which a drop of fat spilled on it would ignite. (Fig.3).

The fats were heated in a cast aluminium pan of 7 in dia., and 3 pints capacity. The lid of the pan had a small slot at the rim to accommodate the handle of the food basket used in some of the tests. The temperature of the heated fat was measured by a sheathed thermocouple inserted through the slot in the lid.

Test programme

Tests on fat heated alone. One litre of each fat was subjected to 8 cycles of heating and cooling in the pan. The heating was carried out on the gas hob for a period of 15 minutes using a rate of supply of town gas of

16.7 ft^3/hr. The chip basket was not used, although the lid of the pan was in place. The sheathed thermocouple was placed centrally and 1 in above the bottom of the pan. The time and temperature were recorded of the first appearance of smoke: (a) when the lid was momentarily removed, and (b) through the slot in the lid with the lid in place. At the end of each heating period the gas was turned off and the pan and contents allowed to cool, with assistance in the latter stages by a draught of air. At the end of each cycle a sample of fat was withdrawn to measure the flashpoint after which the fat was returned to the pan.

At the end of 8 cycles the fat in the pan was again heated but this time heating was continued until the fat ignited spontaneously when the lid was removed (Fig.5). During the heating the smoke points, the flashpoint and the fire point of the fat in the pan were measured, a wax taper being used as a small ignition source for the latter tests. The lid of the pan was replaced after the fat had ignited spontaneously to extinguish the fire and the gas was turned off. As the pan and its contents cooled the lid was lifted and replaced from time to time until spontaneous ignition ceased. The lowest temperature at which spontaneous ignition occurred was recorded.

The fats were examined for deterioration during the tests, the ignition temperature in the E.R.A. apparatus being determined for some of the fats.

Fats used for cooking. The cooking of food in the fats might alter the effect of heating on the ignitability of the fats. Ground nut oil and the three solid fats were therefore tested after repeated use for cooking potato chips. Seven hundred and fifty millilitres of fat were heated on the gas hob using gas at 16.7 ft^3/hr. When the fat temperature reached 190°C (373°F) 290 g of chips in the chip basket were placed in the pan. The quantity of fat, the cooking temperature and the weight of chips cooked, were selected so as to avoid froth-over of fat. The chips were cooked for about 6 minutes, after which time the chips were removed, the gas turned off and the fat cooled; eight such cycles were made. A further test was then made in which the fat was heated alone until spontaneous ignition occurred, the same observations and tests being made as in the first group of tests.

Uneven heating of solid fats. Solid fat was heated in the pan to determine if the lower levels of fat would be overheated before the bulk of the fat became liquid. The sheathed thermocouple was placed close to the bottom of the pan for these tests.

Comparison of heating systems. A comparison was made of the heating of 1 litre of fat in the pan using the three appliances. Heating rates were adjusted on the electric plates where necessary to give a rate of heating of the fat no greater than that of the gas appliance. The temperatures reached by the surfaces of the appliances were measured in this group of tests.

Ignition of fats on hot surfaces. The temperature of heated surfaces on the three appliances, required for the ignition of a small drop of fat from a No.14 hypodermic needle, was measured. All fresh and used fats were tested on the solid electric plate using the special control system. (Fig.3). Used fat only was tested on the other two appliances. For the gas burner the size of the drops of fat was increased to 0.25 ml.

Table 2

Flash point and smoke point of fats heated alone

		1st Cycle			2nd Cycle			3rd Cycle			4th Cycle			5th Cycle			6th Cycle			7th Cycle			8th Cycle		
		Flash Point	Smoke Pt.		F. Pt.	S. Pt.		F. Pt.	S. Pt.		F. Pt.	S. Pt.		F. Pt.	S. Pt.		F. Pt.	S. Pt.		F. Pt.	S. Pt.		F. Pt.	S. Pt.	
			Lid off	Lid on		Lid off	Lid on		Lid off	Lid on		Lid off	Lid on		Lid off	Lid on		Lid off	Lid on		Lid off	Lid on		Lid off	Lid on
Corn Oil	°C	254	173	212	246	173	218	241	135	239	243	135	177	243	132	188	241	121	173	232	132	188	227	121	205
	°F	490	343	414	475	343	425	465	284	462	460	284	351	470	270	371	465	250	343	450	270	371	440	250	402
Ground Nut Oil	°C	260	151	179	257	174	230	260	190	254	234	184	249	238	172	248	243	159	194	256	157	204	243	152	174
	°F	500	304	354	495	345	446	500	374	490	455	363	480	460	341	478	470	318	381	470	315	399	470	306	345
Olive Oil	°C	234	N.D.	N.D.	229	N.D.	224	232	184	N.D.	218	N.D.	210	218	155	N.D.	216	N.D.	202	213	156	194	218	159	182
	°F	455	N.D.	N.D.	445	N.D.	435	450	363	N.D.	425	N.D.	410	425	311	N.D.	420	N.D.	396	415	313	382	425	318	360
Lard	°C	249	186	206	241	186	215	232	175	215	229	145	188	227	163	201	238	138	185	221	121	203	218	134	145
	°F	480	367	403	465	367	419	450	347	419	445	293	370	440	326	394	460	280	365	430	250	398	425	273	293
Dripping	°C	254	179	220	249	154	196	249	159	244	252	167	231	246	153	207	246	144	205	*224	*150	*245	241	157	212
	°F	490	354	428	480	309	385	480	319	471	485	333	448	475	308	404	475	291	401	*435	*302	*472	465	315	414
Hydrogenated Cooking Fat	°C	260	214	231	274	156	218	268	158	209	254	146	232	234	95	154	254	134	184	210	136	194	210	135	184
	°F	500	418	448	525	313	425	515	316	409	490	335	450	455	203	309	490	273	363	410	277	381	410	274	263

*Gas pressure low.

Results

(1) Fats heated alone

The flash points and smoke points for each cycle of heating are given in Table 2. The mean rate of rise of temperature of the eight repeated heatings for each fat tested is given in Fig.6. The rate of rise of temperature varied between cycles, but the differences were small and probably not significant. These differences were due to slight differences in the ambient conditions, and to slight differences in the initial temperature of the fat in the pan. After making due allowance for the differences in initial temperature, the differences between fats are also probably not significant.

Flash point and smoke point reduced in value as the number of cycles increased, the smoke point reducing at a greater rate than the flash point. The hydrogenated cooking fat behaved exceptionally in that the flash point at first increased, and did not decrease to below its initial value until after the third cycle. Differences between the final flash point and smoke point of the six fats were small, the lowest flash point being given by the hydrogenated cooking fat. All fats became more discoloured, and the liquid fats thickened, as the number of cycles increased. Dripping sputtered slightly during the first heating cycle, but not in subsequent cycles. No sputtering occurred with the other fats.

The rate of change of temperature during the spontaneous ignition tests of ground nut oil is given in Fig.7. A similar test on fresh ground nut oil was made for comparison and the result is given in Fig.8. The pressure of the gas main was low for this test, resulting in a lower rate of rise of temperature. The flash, smoke and fire points and initial and final spontaneous ignition temperatures for all the heated fats are given in Table 3. The values of smoke, flash and fire points with the lid lifted are similar for each of the used fats as also are the initial and final spontaneous ignition temperatures. Although the values of smoke and flash points are higher for the fresh fat during heating, probably due to the lower rate of heating, the spontaneous ignition temperatures and the final flash point are similar to those of the repeatedly heated fats. The fire point and the first spontaneous ignition temperature were similar for all fats and had values of about 330°C - 360°C (620°F - 670°F). The final spontaneous ignition temperature for the fats was about 280°C (535°F) although a value for the fresh ground nut oil was rather less than this.

The effect of the heating cycles on the ignition temperature measured in the ERA pattern apparatus was examined for olive oil, lard and the hydrogenated fat. The ignition temperatures for the fresh and used fats were : olive oil 416.5°C and 409.5°C; lard 419°C and 406.5°C; and hydrogenated cooking fat 403°C and 410°C respectively. The differences are small and probably not significant.

The behaviour of the pan of fat leading to spontaneous ignition was fairly consistent. When the lid was removed from the pan, the fumes at first ascended as a simple rising plume. Shortly before ignition this pattern was confused by a toroidal circulation of the fumes, which circulated upwards from the edge of the pan and downwards towards the centre of the pan. A relatively clear central zone was formed, apparently due to the entrainment of air. During this period the fumes became more opaque and whiter in colour, shortly after which the fumes ignited. The fire was readily extinguished by replacing the lid. At temperatures a little lower than the lowest spontaneous ignition temperature, it was sometimes found that, after the lid had been removed and replaced, a vigorous puff of blue smoke would be ejected from the hole in the lid.

The fats ignited spontaneously without any frothing or boiling or any tendency for the fat to be ejected from the pan. The fumes escaping from the pan did not ignite from the gas flame. When the fats had cooled down they were found to have discoloured and thickened considerably.

(2) Fats used for cooking

When the chips were introduced the solid fats tended to spit somewhat but this tendency lessened as the number of repeated cookings increased. The discolouration of the fats was less than was found in the tests in Section (1).

The results of the subsequent tests of heating to spontaneous ignition are given in Table 4. The rate of change of temperature during the test with ground nut oil is given in Fig.9. Smoke and flash points during heating were higher than for the tests in Section (1), but spontaneous ignitions occurred at about the same temperatures with no tendency during the tests for the fats to froth over.

(3) Uneven heating of solid fats

Tests were made with dripping, as this was the most solid fat. The maximum temperature reached near the bottom of the pan, when the fat at the top was solid, was 70°C (158°F), which was about 50°C (90°F) above room temperature.

(4) Ignition of fats on hot surfaces

The results of tests of ignition of drops of fat on the solid electric plate are given in Table 5. There was no significant difference between the temperatures of ignition of fresh or used fats.

Drops of fat from a pan of fat at about 205°C (400°F) were not ignited on any part of the gas hob with the burner alight. However, when a drop of fat fell on to the edge of the burner boss, so that it was touched by the flame, the flame was made luminous for a short time. Drops of fat falling through the gas flame were not ignited.

Drops of fat that were allowed to fall on to the radiant plate, tended to float off the element on a cushion of vapour. Care was therefore taken to place the drop so that this did not occur. The temperature measurements during these tests were unreliable because of the marked cooling of the thermocouple leads. However, it was observed that the tubular element had to be raised above dull red heat for ignition of the drop of fat to occur. The temperatures reached by the surfaces of the heating appliances during cooking are given in section (5).

(5) Comparison of heating systems

The results of these tests are given in Figs 10-12. The rate of heating with the solid plate at full power, 2 Kw, was less than that with gas at 16.7 ft^3/hr (2.4 Kw). A similar rate of heating to that of gas was obtained with the radiant electric plate operated at 1.8 Kw. The setting of the energy regulator to obtain this output was difficult, as the setting was near the point at which the regulator delivered full power. The temperatures of the cast iron parts of the gas hob were substantially lower than the temperature of ignition of fats on hot surfaces, (about 550°C (966°F)) and after 15 min heating were approaching their maximum value. The maximum value for the hottest part is estimated at about 450°C (840°F). The temperature of the solid electric plate was about

460°C (860°F) after 20 min heating but the temperature was still rising steadily, suggesting that the final temperature could well exceed the ignition temperature of fats on hot surfaces. The temperature of the radiant plate reached a mean value of 550°C (966°F) in about 3 min, and the fluctuation of temperature due to the action of the energy regulator was such that the plate would reach 550°C (966°F) at the maximum of a fluctuation in less than 2 min.

Table 3

Fire properties of fats in the pan

	Smoke point		Flash point		Fire point		Initial spontaneous ignition temp.		Final spontaneous ignition temp.	
	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
Ground Nut Oil (Fresh)	191	376	299	570	347	657	362	684	267	513
Ground Nut Oil (Heated)	135	275	250	482	335	635	342	648	280	536
Corn Oil (Heated)	142	288	243	469	321	610	309	588	283	541
Olive Oil (Heated)	N.D.	N.D.	243	469	316	601	340	644	280	536
Lard (Heated)	163	325	275	527	326	619	355	671	282	540
Dripping (Heated)	126	259	246	475	331	628	348	658	276	529
Hydrogenated Cooking Fat (Heated)	140	284	228	442	331	628	355	671	273	523

Table 4

Fire properties of fats after repeated use for cooking

	Smoke point		Flash point		Fire point		Initial spontaneous ignition temp.		Final spontaneous ignition temp.	
	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
Ground Nut Oil (used for cooking)	203	397	286	547	351	664	361	682	279	534
Lard (used for cooking)	206	403	287	549	345	653	355	671	297	567
Dripping (used for cooking)	154	309	247	477	334	633	355	671	272	522
Hydrogenated cooking fat (used for cooking)	190	374	294	561	357	674	362	684	265	509

Table 5

Ignition temperatures of fats on hot plate

	Ignition on solid hot plate			
	Fresh fat		Fat used for 8 cycles	
	°C	°F	°C	°F
Corn Oil	526	977	542	1004
Ground Nut Oil	552	1023	535	992
Olive Oil	562	1041	543	1008
Lard	541	1002	568	1052
Dripping	553	1025	537	997
Hydrogenated cooking fat	568	1052	554	1028

Discussion

Effect of type of fat on fire hazard

The tests reported above show that there was little difference in the fire properties of the fats investigated. In particular the spontaneous ignition temperatures and the fire points, which are the two dangerous temperatures as far as fire hazard is concerned, did not vary substantially for different fats nor were they affected significantly by pre-use of the fat. The initial spontaneous ignition temperatures measured in the pan for both fresh and used fats varied within the range of 309 - 362°C, and the fire points in the pan varied within the range of 316 - 357°C. There were some differences in the smoke and the flash points of the fresh fats but these differences became insignificant after the fats had been used a number of times.

From the point of view of safety of the fats under conditions of overheating it is important to compare the dangerous temperatures mentioned above with the maximum temperature of the fat which would be required for cooking purposes (205°C). No fat under any conditions of test presented imminent danger of fire at a temperature less than 100°C above the cooking temperature. On the other hand all the fats tested under all conditions had become highly hazardous with a temperature increase of 160°C above the normal cooking temperatures. It may be concluded therefore that although there is no evidence that any of the fats was particularly prone to cause a fire during normal use, all fats tested could give rise to dangerous conditions when overheated. Inspection of the heating curves of the fat in Figs. 7, 8 and 9 also shows that the time of overheating required to produce dangerous conditions is about 5 - 10 mins and is generally less than the time required to heat the fat to its normal cooking temperature.

The temperature required to ignite drops of fat on a hot surface was very much higher than that required for fats to become ignited spontaneously in a pan. Here again there was little difference between various kinds of ~~fats or whether the fats were fresh or had been used many times, the ignition~~ temperature for all fats being about 550°C or dull red heat.

Incendive properties of the cooker

The ability of fats to ignite as a result of overheating cannot be attributed particularly to any specific type of cooker since all cookers have the heating capacity not only to heat the fat to cooking temperatures but also to overheat the fat to a temperature where it would spontaneously ignite. Moreover, dispersions of fuel in air in the form of fuel vapour-air mixtures, fine sprays of fuel, and froth or foam can be ignited both by a small gas flame or by a hot surface if the temperature of the latter is sufficiently high. It might be thought that if a fat is heated above the flash point on a gas fired hob, the flames might ignite the fat directly but this did not occur in any of the present tests. There might be a difference, however, between the ability of a gas and an electric cooker to ignite a spillage of liquid fat at temperatures in the region of the cooking temperature. For a stable flame to form on the spillage as it passed through a gas flame it would be necessary for the spillage to be heated to at least the fire point. In the test, spillages of up to a $\frac{1}{4}$ ml in size could not be ignited when allowed to fall through the flames of the gas appliance presumably for the reason that they could not be heated by the required amount as they fell. The tests also showed that the temperatures reached by solid surfaces during the normal use of the cooking appliances were considerably higher for both electrical hobs tested than they were for the gas hob tested. Moreover the temperatures of the surfaces of the gas hob tested levelled out at values substantially less than that required to ignite a drop of oil spontaneously, whereas the surfaces of the electric hot plates tested could or did reach such a temperature.

Although these tests were carried out using only three cooking hobs, it is unlikely that this picture of the maximum temperature of surfaces on the hob would be very different if the range of cooking hobs investigated were extended, unless these incorporated marked changes in design. Broadly this point may be summarised in the observation that drops of oil did not become ignited by a hot surface unless this surface has reached a dull red heat. In general the hot metal parts of gas cookers do not reach dull red heat whereas the hot metal parts of electric hobs do often reach and exceed dull red heat.

Thus if the behaviour of the hobs tested is broadly representative of the behaviour of cookers in use, it may be concluded that an electric cooker is more likely to ignite a spillage of hot oil in liquid form than a gas cooker. It is possible that this might be responsible for some of the extra fires which the available statistics attribute to electric cookers, although no direct evidence of this has been found from recent reports from fire brigades. It is unlikely, if the fat in a pan is at ordinary cooking temperatures, that the ignition of even a substantial spillage would bring about a direct ignition of the fat in the vessel itself. A large momentary flame associated with a spillage, however, could ignite flammable material left carelessly near or above the cooker.

Automatic temperature sensing devices

There is little doubt that many fires caused by heating fats in a pan on a hob are a direct result of the fats being carelessly allowed to overheat to dangerous temperatures. Thus of 750 reported fires caused in 1957 by material being heated or cooked on an electric hot plate or ring, fat was the material first ignited on 649 occasions and in 232 of these occasions it was specifically stated that this fat was left unattended on the cooker. ~~In the remaining 417 occasions the reports are not specific on this point.~~ It is clear that if fat could be prevented from overheating to a dangerous temperature, then a substantial reduction in the number of fires associated with cookers might be achieved. The experimental evidence given in this report suggests that this might be done by providing a device on the hob which automatically shuts off the power supply or the fuel supply once the temperature of a pan exceeds by a predetermined amount the maximum cooking temperature for hot fats. The results presented in this report may be regarded as reasonably representative of the bulk of fats used in cooking and these results show that for all these fats there is substantial margin between the maximum temperature that might be required in any cooking operation (205°C) and a temperature at which a fat becomes immediately dangerous as a fire hazard (310°C). If a pan sensor were designed to operate, for example, within the range of temperature of 220 - 250°C then on the one hand this should leave an ample margin to allow cooking operations at the highest safe temperatures and on the other hand an ample margin before the fat reached temperatures which were immediately dangerous. Pan sensors have been used for a number of years already, for example, to prevent the boiling over of milk. The use of such devices for preventing fat overheating to a dangerous temperature is certainly just as feasible as its use for any other purpose, and the wide limits of temperature available for the device to operate for fat cooking would make its reliable design a less difficult task than its design for other cooking operations.

References

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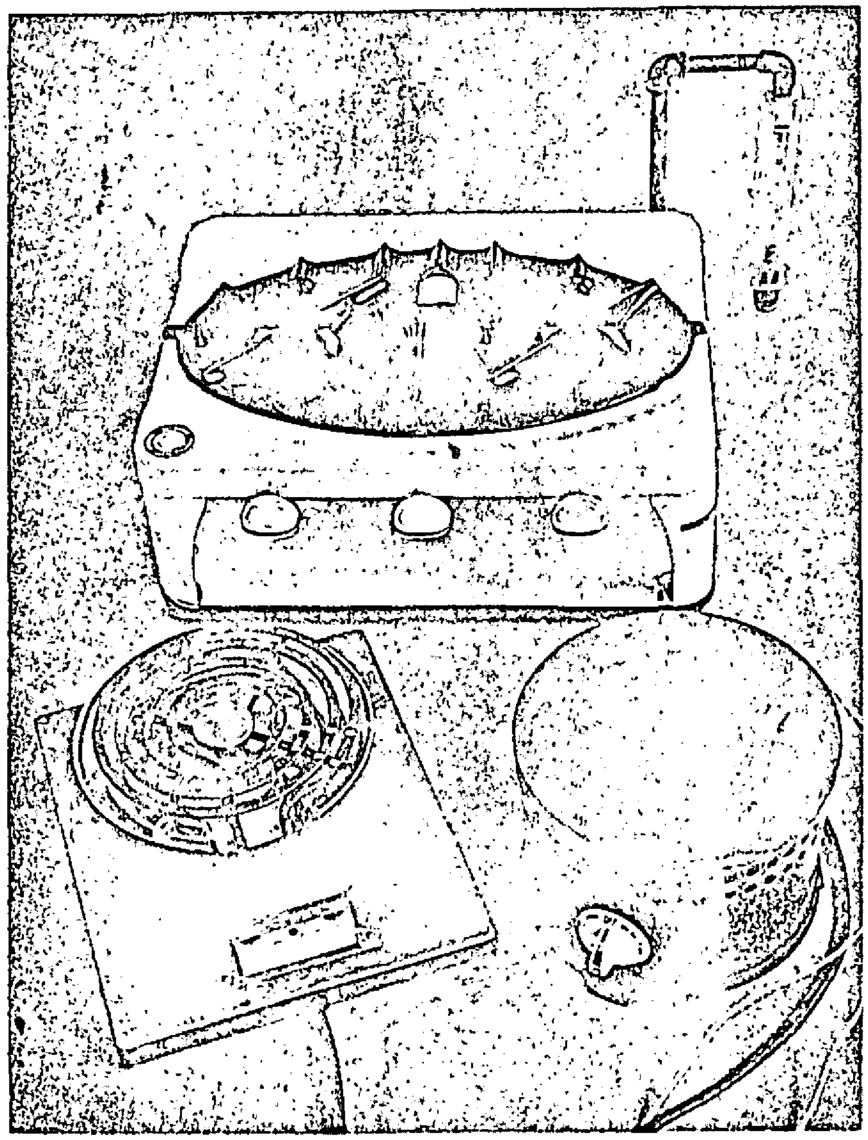
2. United Kingdom Fire Statistics 1962.

3. United Kingdom Fire Statistics 1963.

4. STARK, G. W. V. "Some tests on the flaming properties of cooking oil. 1. Ground nut oil". Internal Note No.82. - L. A.



Top centre - Gas hob
Bottom left - Electric radiant plate
Bottom right - Electric solid plate

HEATING APPLIANCES

FIG. 1

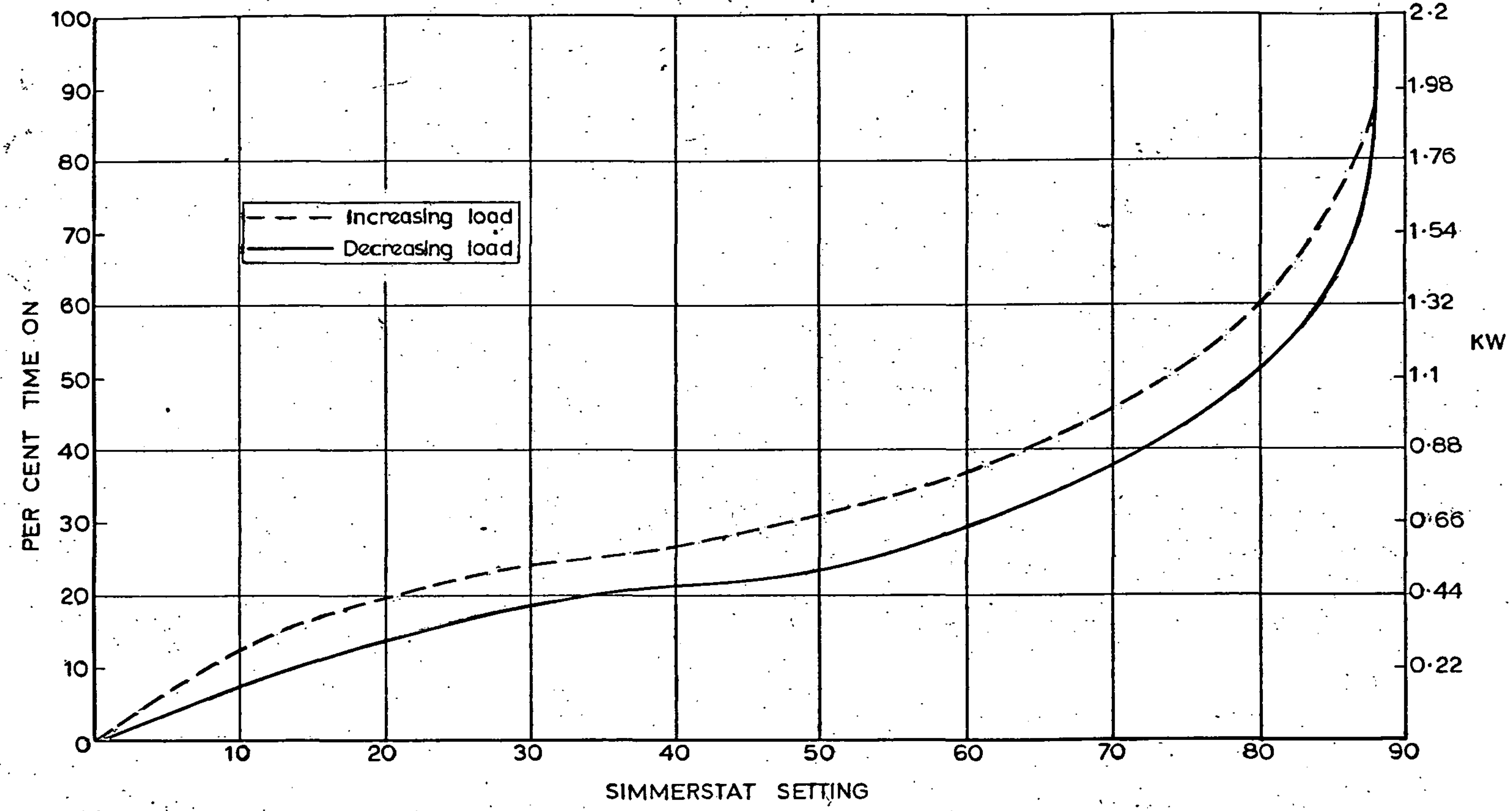
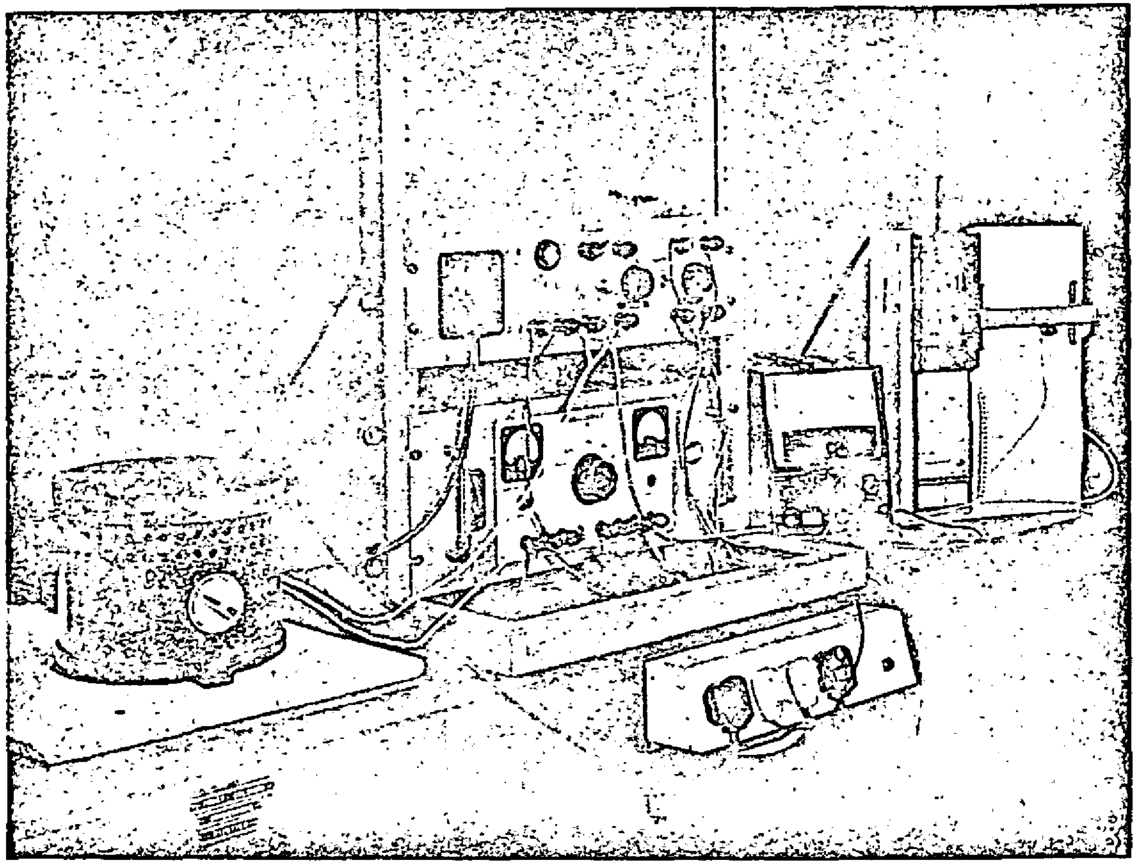
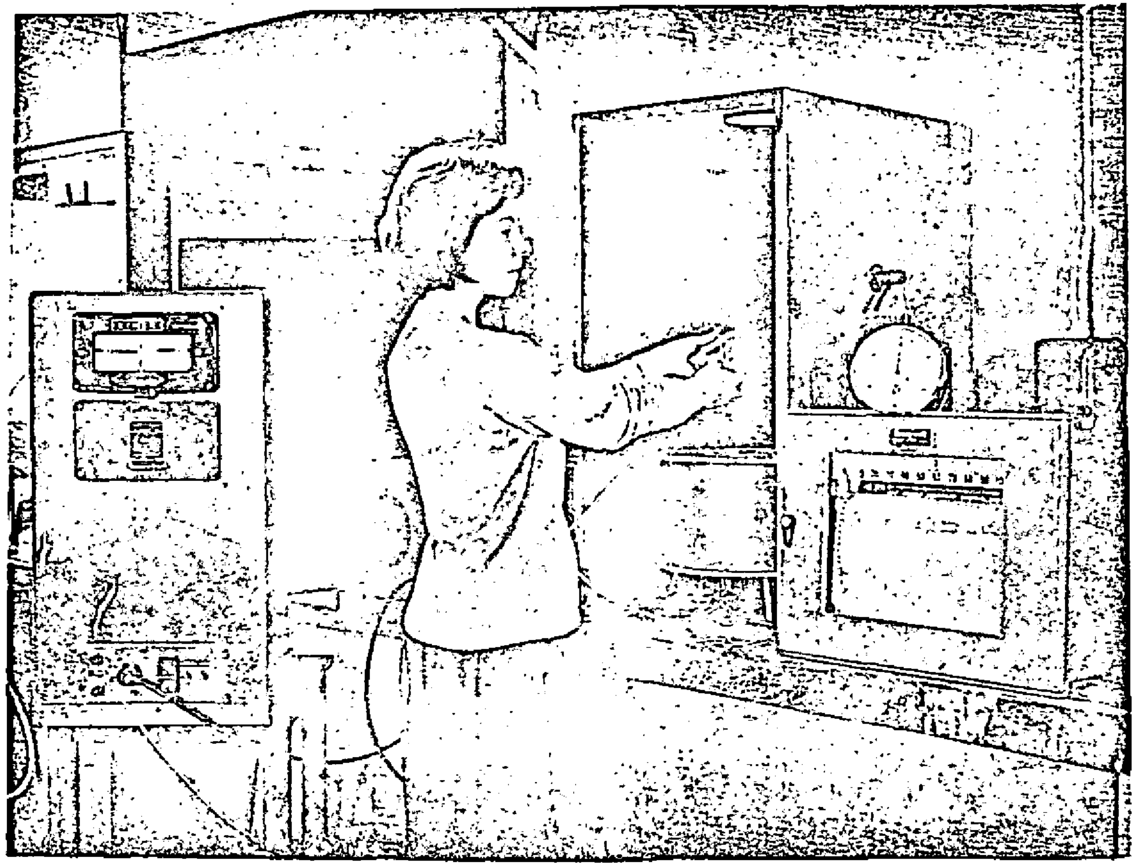


FIG.2. LOAD CONTROL BY ENERGY REGULATOR 2·2 kW RADIANT PLATE



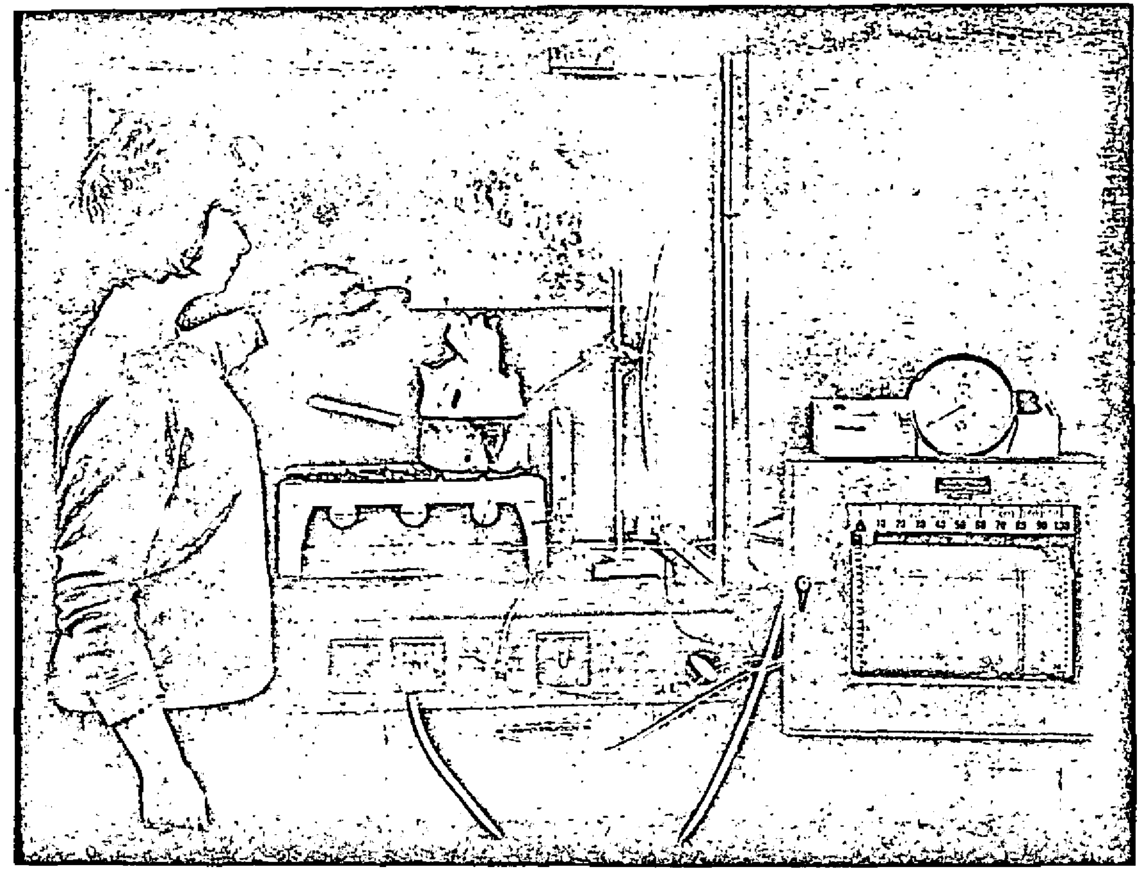
APPARATUS FOR FINE CONTROL OF
TEMPERATURE OF HOT-PLATE

FIG. 3.



IGNITION TEMPERATURE APPARATUS

FIG. 4



THE SPONTANEOUS IGNITION OF
HEATED FAT

FIG. 5.

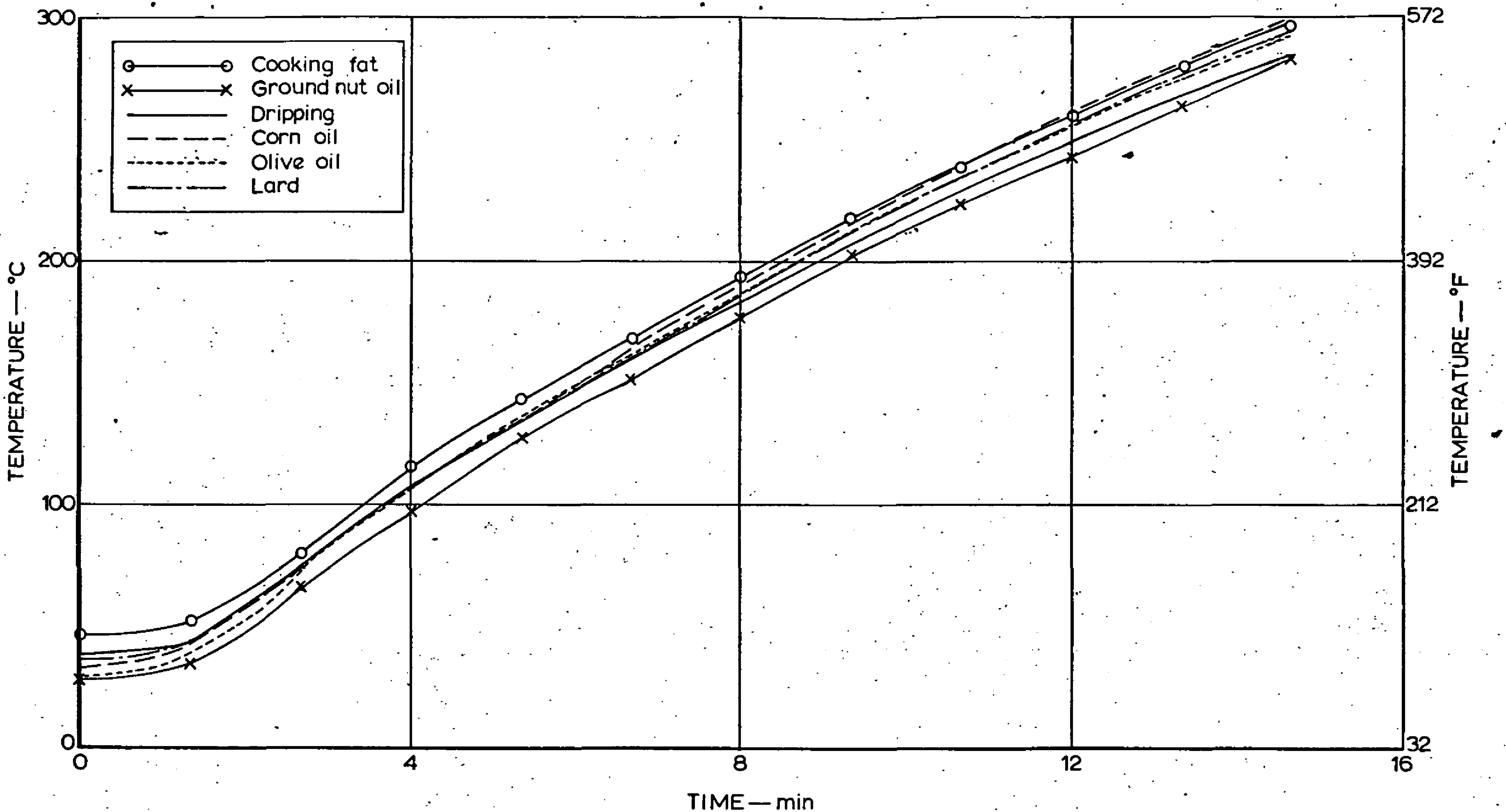


FIG. 6. MEAN RATE OF RISE OF TEMPERATURE OF COOKING FATS ON GAS HOB — GAS RATE 16·7ft^3/hr

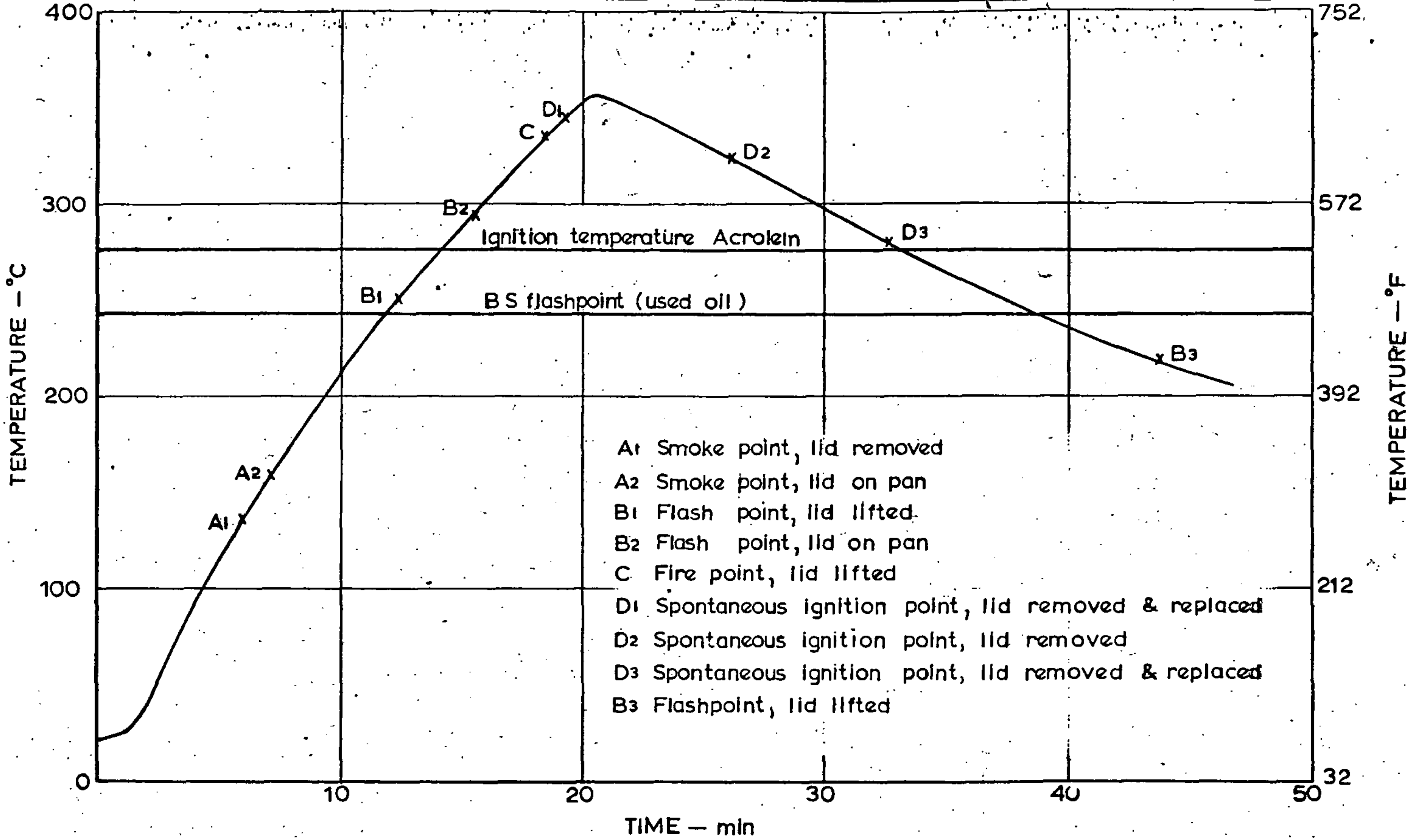


FIG.7. IGNITION TEST – GROUND NUT OIL – GAS RATE 16·7 ft^3/h

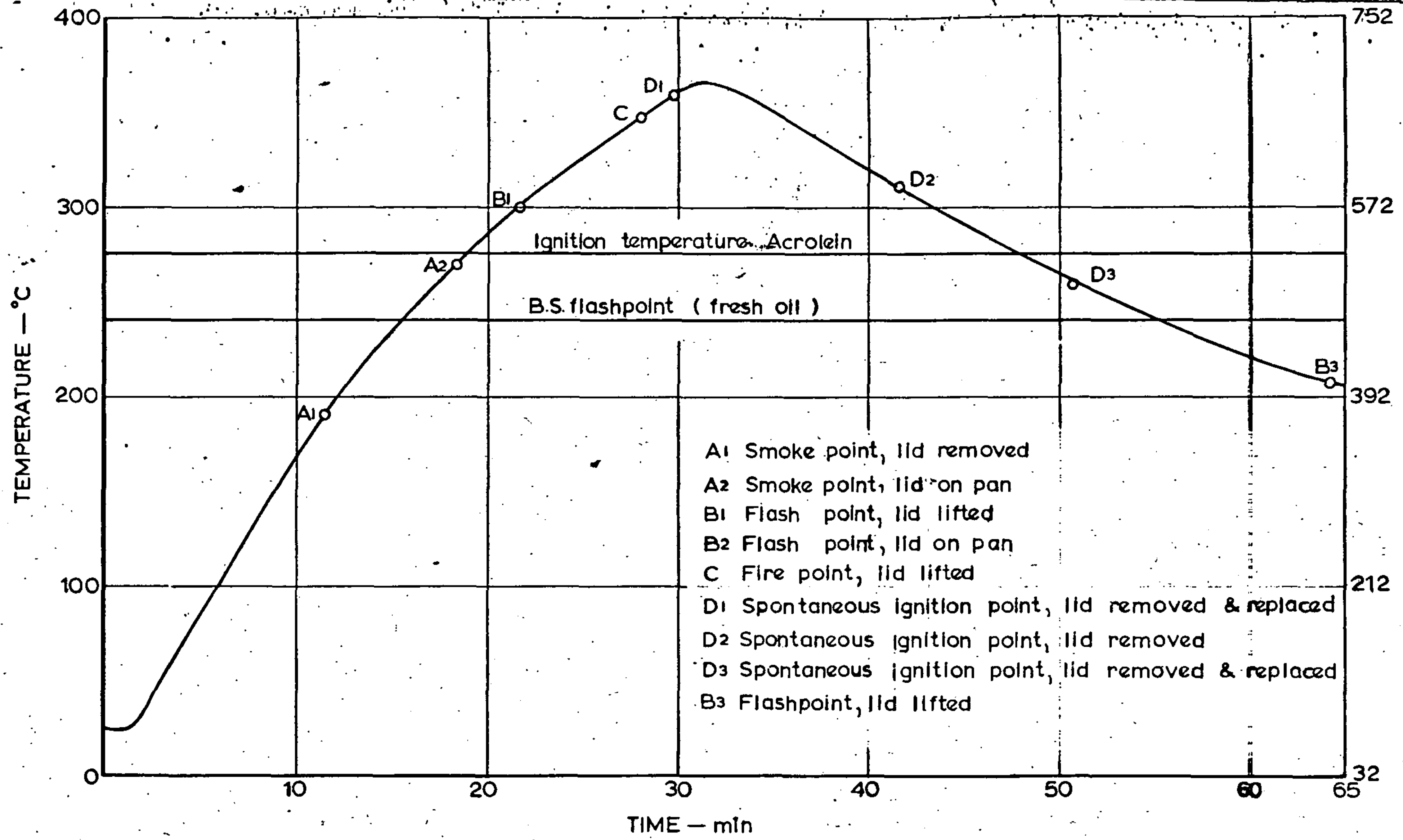


FIG. 8. IGNITION TEST — FRESH GROUND NUT OIL — GAS RATE 13·8 ft^3/h

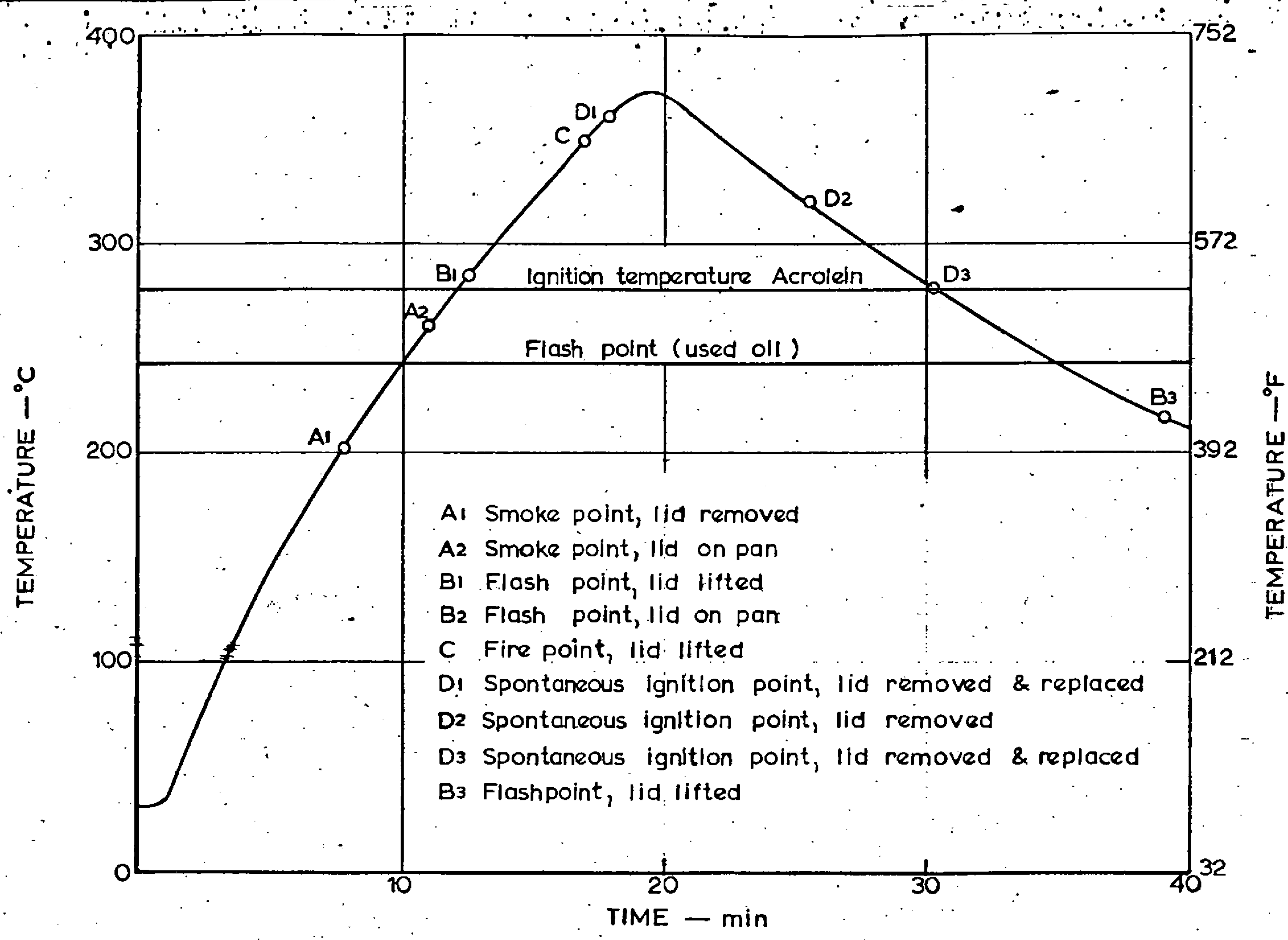


FIG.9. IGNITION TEST – GROUND NUT OIL USED FOR COOKING – GAS RATE 16·7 ft^3/h

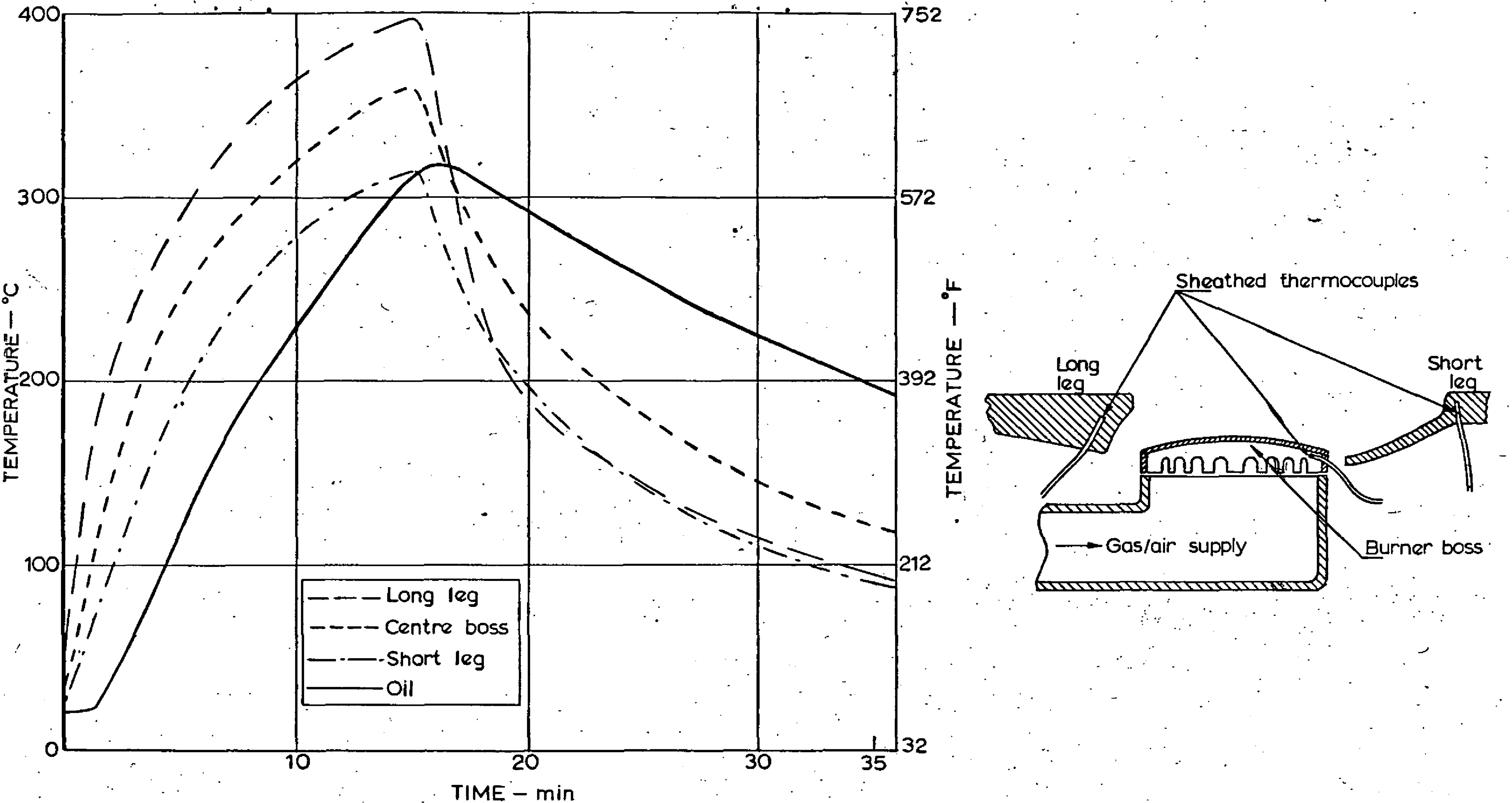
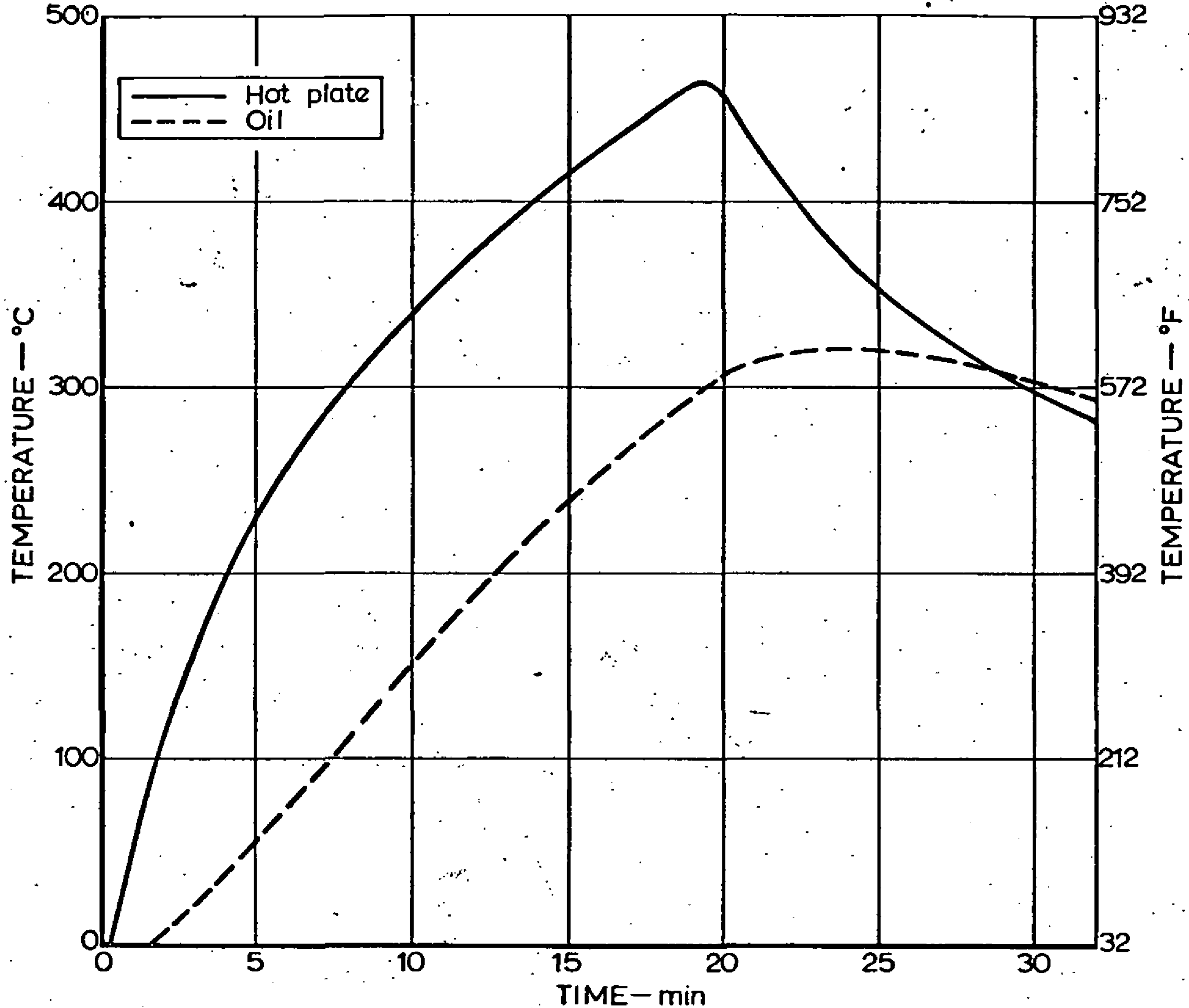


FIG.10. TEMPERATURES ON GAS HOB — GAS RATE 16·7 ft^3/h



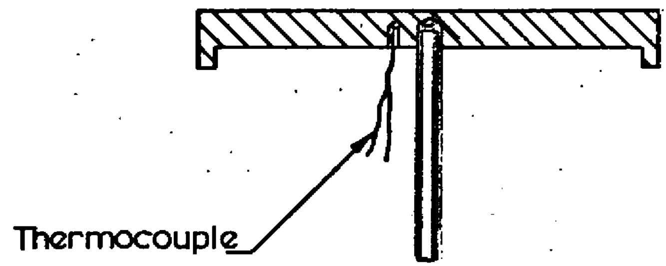
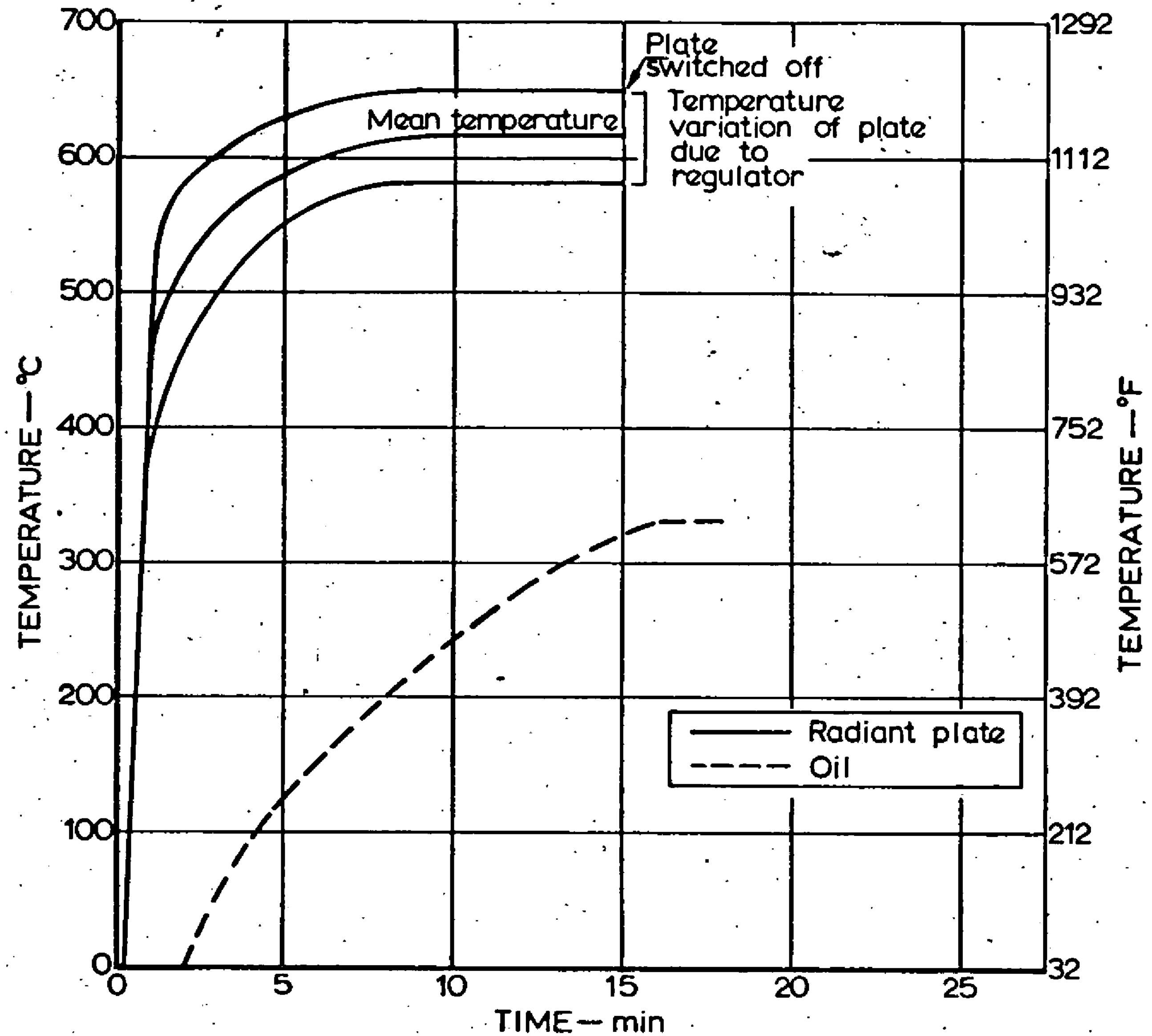


FIG.11. TEMPERATURES ON SOLID HOT PLATE — HEATING RATE 2 kW



Regulator setting = 87
Mean power input = 1·8 kW

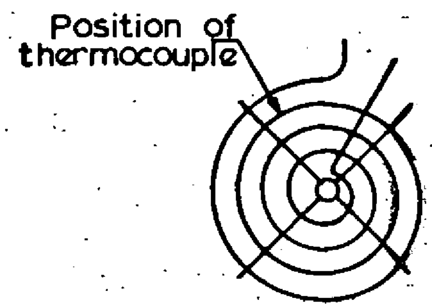


FIG. 12. TEMPERATURES ON RADIANT PLATE — HEATING RATE 1·8 kW