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ROYAL AIRCRAFT ESTABLISHMENT

(FARNBOROUGH)

TECHNICAL NOTE No. WE. 13

KINETIC AND SOLAR HEATING OF 1000 lb. BOMBS EXAMINED AT R.A.F. IDRIS, AUGUST - SEPTEMBER, 1962

by

W. F. Fielding, B.Sc., A.Inst.P.

FEBRUARY, 1963

MINISTRY OF AVIATION

U.D.C. No. 623.451.74 : 533.6.011.6 : 551.521.1

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R O Y A L A I R C R A F T E S T A B L I S H M E N T

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SUMMARY

This Note gives the results of experiments carried out with 1000 lb Mk.10 bombs at R.A.F. Idris, August-September, 1962.

Values are given for the temperatures recorded on and within bombs stored in full sunlight. It is inferred that there is little danger of the filling melting even under the worst tropical conditions.

Results of flight trials confirm the tables of speed restrictions previously issued (R.A.E. Tech. Note No. Arm 704) for external carriage of V.T. fuze No.906 and 1000 lb bombs.

Some information is given regarding the met. conditions at Idris during the period of the trials.

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1 INTRODUCTION

During the recent Buccaneer tropical trials at R.A.F. Idris, Libya, August-September, 1962, an R.A.E. team attended to study the behaviour of various weapons under tropical or near-tropical conditions.

This Note is concerned solely with tests on the 1000 lb Mk.10 bomb (although the results are applicable equally to the 1000 lb N.1 bomb) and covers the following conditions:-

(a) heating of the bomb when stored on the ground in the sun,

(b) heating of the bomb on the aircraft pylon, with the aircraft standing in the sun on the ground,

(c) heating of the bomb in the aircraft bomb bay during flight,

(d) kinetic heating of the bomb in flight when carried externally on the aircraft pylon.

Case (a) was covered adequately in the period before the aircraft arrived at Idris, but owing to the short time during which a serviceable aeroplane was available (5 days) for all the tropical trials, only one test could be made under each of cases (b) to (d).

In addition to the heat measurements made on the bombs, solar radiation intensity was measured near by and data on shade temperature, wind speed and direction, humidity and low cloud coverage was obtained from the Idris Met. Office.

Most of the trials undertaken had as aim the verification of previously-propounded theories on bomb heating under near-tropical conditions. This was done, as far as possible, but flight limitations imposed on the aircraft (550 knots maximum speed, with air temperature not to exceed 35°C) made it impossible to obtain as high bomb temperature increases over U.K. summer flight conditions (lower air temperatures but higher aircraft speeds) as had been hoped for.

2 WEATHER CONDITIONS

Owing to delay in starting the trials (August 21st instead of mid-July) the air temperatures experienced at Idris were not as high as had been expected, being generally in the low 30s centigrade, with the occasional excursion to 35°C.

There were many cloudless days, but cloud cover tended to increase towards the end of the trials (mid-September) and for several days at the end of August sand-storms were blowing.

Appendix 1 gives details of:-

shade temperature,
humidity,
low-cloud cover,
wind speed and direction,
solar radiation,

for the days on which the trials reported in this Note were carried out.

The Appendix also gives maximum and minimum shade temperatures for the whole period of the trials.

The solar radiation was measured with a Kipp Solarimeter which had been calibrated at Kew Observatory.

3 INSTRUMENTATION

3.1 Bomb

The 1000 lb Mk.10 bomb was fitted with eighteen platinum-law resistance thermometer elements arranged in two groups of nine as shown in Fig.1.

Of each group of three elements, one was just below the surface of the bomb skin, one was at the surface of the bomb filling and one was 3 cms deep in the filling.

Full details, with diagrams, are given in Ref.1, the only difference being that for the trials described in this Note the cables from the thermometer elements were brought out from the rear fuze well and not from a hole cut in the top of the bomb.

The instrumented bomb was filled with an inert substance having heat properties as close as possible to those of Torpex 2A (see Ref.1, Appendix 1) and connexions were provided into the nose fuze well so that a V.T. fuze, instrumented with two resistance thermometer elements (one on the power pack, one on the amplifier) could be connected if desired.

3.2 Recording

Two methods were used for recording temperatures. For the ground trials, the leads from the thermometer elements were connected to a selector box in which each element could, in turn, be connected to a ratiometer which gave a direct temperature reading.

For flight trials, the same method could not be used and a photographic recorder was constructed to fit inside the bomb tail, mounted on anti-vibration mountings. (See Appendix 2 for details.) Once every minute twelve of the thermometer elements in the bomb (the desired twelve being selected before the trial) were sampled automatically, connected to a ratiometer, and the ratiometer dial together with an adjacent clock photographed after allowing five secs for the ratiometer needle to take up its correct position on the dial.

This cycle of twelve samples per minute could be repeated for as long as the recorder was switched on. Power from the recorder was obtained from the pylon or bomb bay (for external or internal carriage respectively) and fed to it either through a two-pin plug in the base of the tail (internal carriage only) or via leads which entered the bomb through the E.L. fuzing position and emerged from the tail fuze well to be connected to the recorder.

In practice, it was found better to sample eleven resistance elements in turn and to leave the twelfth position unconnected to form an identification point once in each cycle.

The accuracy of the system is such as to give mean temperature rises correct to $\pm 2^{\circ}C$. Before test, care was taken to ensure that the bomb was stored in such a way that its temperature was reasonably constant throughout. The mean value obtained from a pre-test record was taken as the initial temperature of the bomb. Bomb temperatures throughout the trial were then obtained by adding this result to the values of temperature rise obtained from the film.

4 GROUND TRIALS

4.1 Bomb on ground trolley

Three trials were carried out with the bomb on a bomb trolley inside a compound such that it was effectively shielded from wind but was in the full sun for most of the daylight hours (06.30-20.00 hrs local time, G.M.T. + 2 hrs). The shielding from wind was not intentional.

The trolley was placed in position after dark the previous evening (this was dictated by other trials carried out in parallel) and left in position all night, recording starting at 04.00 hrs the next morning and continuing until 04.00 hrs of the next day.

The conditions of test were as follows:-

Trial 1, bomb in north-south orientation with nose to south. No tail fitted. V.T. fuze No.906 fitted.

Trial 2, bomb in east-west orientation with nose to east. No tail fitted. No V.T. fuze fitted.

Trial 3, bomb in east-west orientation with nose to east. Tail No.114 fitted. No V.T. fuze fitted.

Tables 1-3 show the temperatures attained during the three trials together with the relevant met. data; Figs.2-10 show the temperature data in graphical form.

4.2 Bomb on pylon

One trial (No.4) was conducted with the bomb mounted on the inboard port pylon of the aircraft parked on the airfield with its nose pointing west.

Again, the bomb was put into position the previous evening, but owing to aircraft servicing requirements recording was only possible between 09.30 hrs and 14.00 hrs, during which time the bomb was almost completely shaded from direct sunlight by the aircraft wing. It was not shielded from such wind as was blowing.

Table 4 shows the results obtained.

4.3 Results obtained

4.3.1 Comparison between Figs.2, 5 and 8 shows clearly the different effect arising out of the direction in which the bomb was pointing. In Fig.2, with bomb pointing south, the sun was on the port side during the morning, then changed to the starboard side for the hottest part of the day (14.00-16.00 local time).

In Figs.5 and 8, the bomb nose pointed to the east and the starboard side was in the sun all day long, with the port side partly shaded from direct sunlight by the top of the bomb.

For all three cases, the bottom of the bomb never received full, direct sunlight and the temperature rises there are only slightly greater than those of the ambient shade temperature, augmented, perhaps, by some slight reflexion from the ground.

Figs.3, 6 and 9 show that in only one case does the temperature at the surface of the bomb filling exceed 50°C, and that only marginally.

During the hours of darkness the bomb cools steadily and by dawn next morning is completely cooled to air ambient temperature which, for the duration of the trials, was generally slightly below 20°C.

Considering the state of affairs at a depth of 3 cms into the filling (Figs.4, 7 and 10) we see that the maximum mean temperatures for the three trials are 42, 34 and 38°C respectively with an over-all mean of 38°C. Individual points exceed these values for a time, but nowhere do the temperatures approach near to the melting point of Torpex (70-80°C). The amount of filling to a depth of 3 cms is about $\frac{1}{3}$ the capacity of the bomb and consequently the major part of the filling will be at a temperature of less than the 38°C quoted above, which itself represents a temperature rise of about 18°C.

Even under maximum temperature atmosphere conditions the initial morning temperature would probably be not very much in excess of 20°C. If the bomb filling temperature rose by twice the amount found in these trials (and this is most unlikely) it would still be considerably below melting point.

It appears, then, that there is little danger of the bomb filling melting (except perhaps for very local melting at the surface of the filling) during ground storage and that a maximum mean temperature of 35°C for the filling, as has been assumed previously (Ref.1), is reasonable.

Some protection is usually provided for stored bombs, and even a tarpaulin sheet would reduce local temperature rises considerably (see para.4.3.3).

4.3.2 The V.T. fuze, (Trial No.1, Table 1) did not appear to heat up quite so much as might have been expected. It is, however, a light structure, very susceptibel to cooling from changes of ambient temperature and by conduction into the bomb.

4.3.3 On the pylon, very little temperature change was noticed during the period of the test, since the bomb was almost completely in the shade from the aircraft wing throughout the whole period and was also exposed to the wind (up to 7 knots from a south-easterly direction). Table 4 shows the temperatures reached and the met. conditions for the day.

This trial shows how effective some shielding from direct sunlight can be in keeping down bomb temperatures; trials carried out on other stores at the same period showed that a simple awning of dark cloth on a light frame made a considerable reduction in store temperature as against the case of no shielding.

It is probable that on the Buccaneer less shading would have occurred on the outboard pylons, but as these are not yet available, it could not be tried.

Only one trial could be carried out on the pylon since this was the only occasion on which the aircraft stood out in the sun for a long period.

5 FLIGHT TRIALS

5.1 Bomb in bomb bay

Since the available flying time of the aeroplane was so short, only one flight could be carried out with the instrumented bomb and three uninstrumented ones in the bomb bay, with the instrumented one in the forward port position when the bomb doors were closed.

The 906 V.T. fuze was fitted to the bomb and in addition "Temp-plate" temperature indicators were attached to the ejector release units as close to the cartridges as possible.

The flight was made with bomb doors closed under the following conditions (Trial No.5):-

Speed 550 kts (M = 0.81).
Height 500 ft.
Duration 40 minutes.
Air temperature 30°C.

Table 5 gives the temperatures recorded in bomb and fuze. Fig.11 is a plot of the temperatures.

5.2 Bomb on pylon

Again, only one flight was possible (Trial No.6) with the instrumented bomb on the port inner pylon and an uninstrumented one on the corresponding starboard pylon.

Before arriving at Idris the pylons had not been fitted to this aircraft, even for trial, and consequently no power supply to run the recorder was available in the pylon. One was eventually improvised, sufficient for this one flight.

With the pylons supplied with this aircraft there were no fairings to fill the gaps between bomb and sole plate at bomb nose and tail, and in consequence there was a free path for air to be forced into the pylon and over the E.R.U. with a possibility of seriously overheating it[2].

Consequently an initial flight was carried out at a speed of 450 kts (with the instrumented bomb replaced by an uninstrumented one) with the E.R.Us fitted with "Temp-plate" indicators as for the internal carriage. After the flight, the E.R.U. temperatures had not exceeded 65°C and it was decided to be safe to carry the instrumented bomb at 550 kts (aircraft maximum for those temperature conditions).

Table 6 gives the temperatures measured; Fig.12 gives the temperature data in graphical form.

5.3 Results obtained

5.3.1 In the bomb bay, most of the heat is derived from internal sources (hot air exhausted into the bomb bay) rather than from kinetic heating of the aircraft skin. This internal heating takes place whenever the engines are run on the ground or in the air, and pre-flight running of them accounts for the high (32°C) initial bomb temperature (Fig.11).

Only at the end of the flight was the temperature beginning to level off on the bomb skin, whilst it was still rising inside. In an empty bomb bay, air temperatures of about 80°C have been recorded. The large thermal inertia of 4 x 1000 lb bombs is such that they are here settling down to a steady temperature well below 80°C. This accords with the results of trials undertaken on a mock-up bomb bay[3] to investigate the kinetic heating of bombs placed in it. Those bombs took longer to heat, since the heating was purely by convection from the heated bomb bay skin, there being no flow of hot air as in this case, but in no case, even after prolonged heating, did they attain a temperature anything like the air temperature reached in an empty bomb bay under identical heating conditions.

For the flight conditions used, the aircraft skin temperature would have risen to about 63°C, slightly lower than recovery temperature (66°C), so there would have been some tendency for heat from the hot air flow to flow outwards from the bomb bay as well as into the bombs.

The V.T. fuze, being a light structure, heats up more than does the bomb and its final temperature (65°C mean) is probably a reasonable assessment of effective bomb bay temperature. In this flight its temperature was such that its sensitivity would be almost halved; when higher speeds become possible with this aircraft it will over-heat even more unless the bomb bay hot air flow can be reduced.

The E.R.U. cartridges did not overheat in the bomb bay. Their maximum temperatures being less than 65°C.

5.3.2 On the pylon, the bomb skin quickly rises to within a few degrees of recovery temperature, as would be expected[1], but there is no serious overheating of the bomb filling during the flight period. The limitation is that the filling temperature must not exceed 80°C at a depth of 3 cms. Under the conditions of this flight (speed M = 0.81, ambient temperature 30°C) Ref.1 shows that flight should be possible at M = 1.65 for 40 minutes before overheating of the filling occurred.

The same paper also shows that the corresponding flight limitation on the V.T. fuze (before its temperature reached 70°C) would be M = 0.9. This agrees well with the 65°C found in this flight at M = 0.81.

After the flight the E.R.U. cartridges were found to have reached a temperature of 75°C which exceeds the temperature (70°C) to which they are tested.

Until fairings are provided on the pylon, it seems likely that E.R.U. and V.T. fuze temperatures will provide flight limitations rather than bomb temperatures.

After the flight, the two upper tail attachment screws (No.114 tail) were loose by about one turn, although they were tightened as hard as possible before flight.

6 COMPARISON WITH THEORETICAL FIGURES

A previous paper[4] showed that for a homogeneous body such as a conventional bomb, a good approximation to the temperatures occuring at any point within the filling after a given time from start of heating, could be obtained by treating the bomb as a cylinder of explosive and using standard conduction theory for such a body, with a known skin temperature.

Table 6 and Fig.12 show the temperatures calculated on this basis for a point 3 cms into the bomb filling, using the measured values of bomb skin temperature. These calculated values agree with the measured ones at the same depth to within 2-3°C, the calculated ones being slightly higher than the measured ones.

This is to be expected, since the theory neglects, for simplification, the bitumen layer between bomb case and filling, but the agreement is close enough to permit use of theoretical values in future, at least initially, with, possibly, confirmatory flight tests later on.

The values of flight limitations given in Ref.1 should now be considered as accurate for external carriage of 1000 lb bombs and 906 V.T. fuzes. For convenience, these flight limitations are reproduced here as Tables 7 and 8.

7 CONCLUSIONS

(1) The use of theoretical temperatures for a regularly-shaped and homogeneous store, as advocated in R.A.E. Tech. Note No. Arm 702, is justified, and gives results slightly higher than would be obtained in practice.

(2) Bombs stored out in the sun under tropical or semi-tropical conditions will have a maximum mean filling temperature of about 35°C. At no point are they likely to become hot enough to melt the filling.

A simple awning on a light frame would reduce the heating considerably.

(3) When the Buccaneer is standing on the ground, bombs on the inboard pylons do not suffer much temperature increase, due to shielding from the sun by the aircraft wing.

(4) No.906 V.T. fuzes overheat when carried in the Buccaneer bomb bay due to the high temperatures there, arising from the injection of hot air from elsewhere in the aircraft.

(5) The tables of flight limitations for externally-carried 1000 lb bombs and No.906 V.T. fuzes given in Tech. Note No. Arm 704 are reasonably accurate.

(6) Fairings are required between bomb and pylon sole plate to prevent hot air entering the pylon and overheating the ejector release units.

8 ACKNOWLEDGEMENTS

Acknowledgement is made to Mr. R.S. Howell, Weapons Dept., R.A.E., who built and tested the photographic recorder and to the O.C, and personnel of The Overseas Experimental Unit, at R.A.F. Idris for the invaluable assistance rendered in many ways throughout the period of the trial.

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Ref. No.	Author	Title, etc.
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2	Russell, C.P. Jnr	Investigation of aerodynamic heating of external stores (F-100, F-101, F-105 aircraft). APGC-TR-60-9. April, 1960.
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4	Fielding, W.F.	A theoretical examination of the problem of the kinetic heating of externally-carried aircraft bombs. R.A.E. Tech. Note No. Arm 702, October, 1961.

ATTACHED:

Appendix 1 (including Figs. App.1/Figs.1 & 2, Drg. Nos. WE.R.3192, 3193.)
Appendix 2 (including Figs. App.2/Figs.1-3,(Drg. Nos. WE.R.3194, 3195 and
Tables 1-8 (Neg. No. 160,661.)
Illustrations, Figs.1-12 (Drg. Nos. WE.R.3196-3207)
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APPENDIX 1

MET. CONDITIONS FOR THE TRIAL PERIOD AT R.A.F. IDRIS

During the period of the trials solar radiation intensity was measured on a good many days at a site adjacent to the trial.

Forevery day of the trials (21st August to 20th September) the following data was obtained from the Idris Met. Office for hourly periods throughout the whole day:-

Shade temperature (^{o}C).
Wind speed and direction.
Humidity.
Sea-level pressure.
Low cloud cover.

Table 1 of this Appendix gives this data for the days on which Trials 1-6 were carried out.

Figs.1 and 2 of this Appendix shows the daily maximum and minimum temperatures throughout the whole period together with the number of hours per day on which the temperature:

(a) exceeded 30^{o}C
(b) exceeded 35^{o}C.

ATTACHED:

Drg. Nos. WE.R.3192-3193

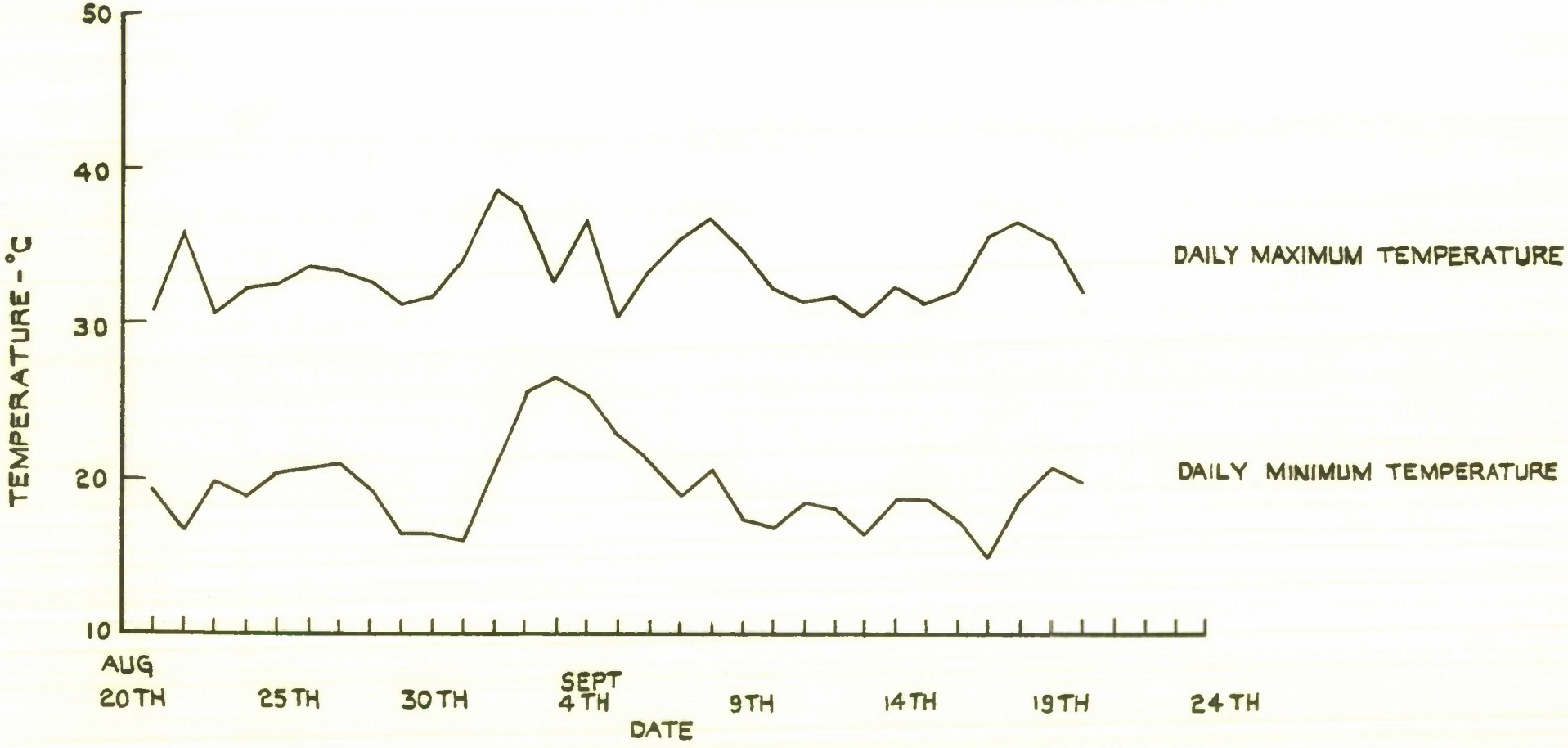

FIG. 1. DAILY MAXIMUM AND MINIMUM TEMPERATURES FOR THE TRIALS PERIOD. IDRIS, AUGUST 20TH TO SEPTEMBER 20TH 1962.

T.N.W.E. 13
APPENDIX 1
FIG. 1.

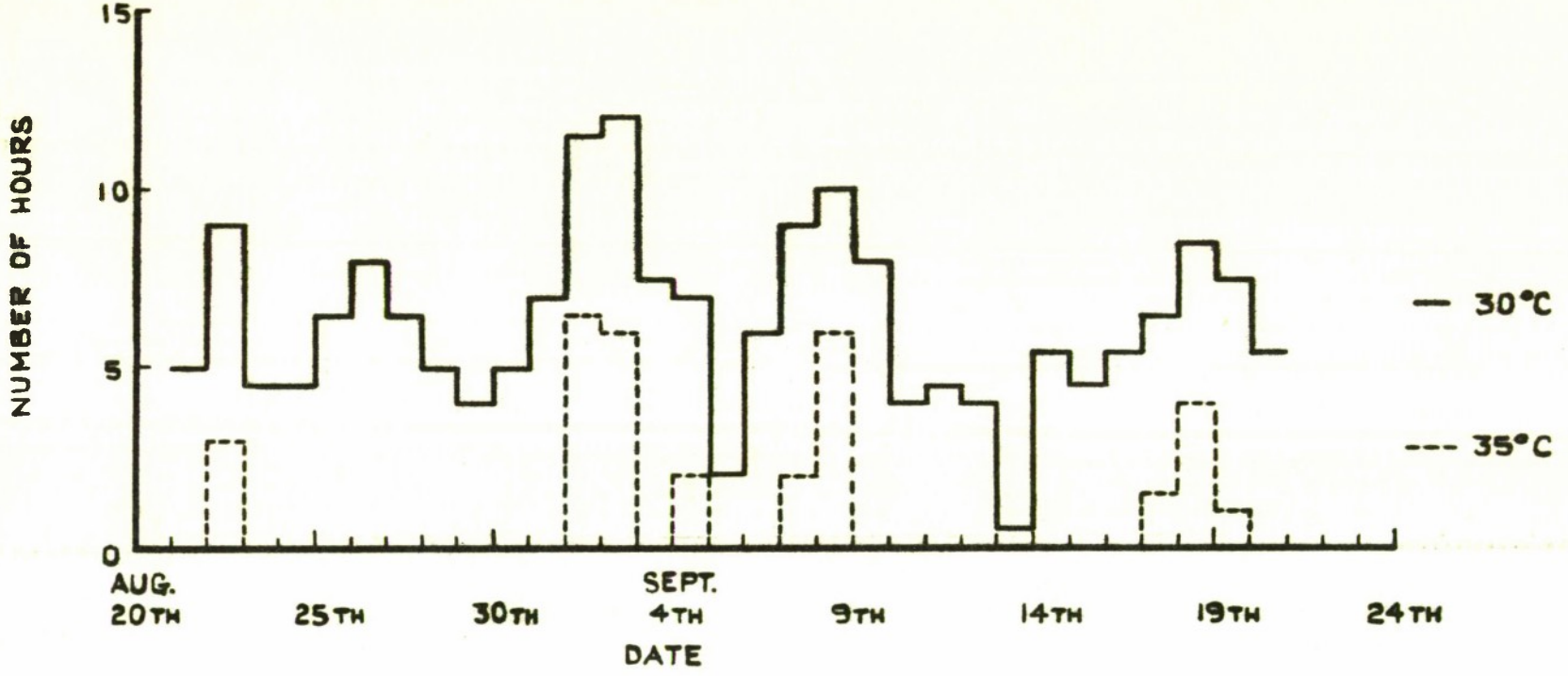

FIG.2. NUMBER OF HOURS PER DAY FOR WHICH THE TEMPERATURE EXCEEDED 30°C AND 35°C AT IDRIS, AUGUST 20TH TO SEPTEMBER 20TH 1962.

T.N. WE.13
APPENDIX I.
FIG.2.

TABLE 1

Met. conditions for the days of Trials Nos.1-6

Quantity measured	Date	Time (local time = G.M.T. + 2 hrs) 01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00
Shade temperature (°C)	22nd	19.8	19.1	17.6	17.6	17.0	16.6	17.8	21.4	22.4	30.0	31.4	33.2	34.6	35.0	35.9	35.3	35.0	33.4	30.6	28.6	27.0	26.3	25.2	24.2
Wind speed (knots)	Aug.	Calm	Calm	Calm	Calm	Calm	Calm	Calm	Calm	Calm	02	06	06	08	05	07	07	10	13	13	10	10	06	02	Calm
Wind direction (degrees)	1962	Calm	Calm	Calm	Calm	Calm	Calm	Calm	Calm	Calm	320	350	340	330	010	360	020	020	030	040	050	040	030	050	Calm
Humidity (%)		85	85	84	82	81	77	61	53	60	37	30	26	25	28	26	25	28	33	44	56	70	71	76	78
Sea-level pressure (MBS)		1014.1	1013.9	1013.7	1013.7	1013.7	1013.3	1013.5	1013.5	1013.9	1014.2	1014.5	1014.7	1014.4	1014.1	1013.8	1013.4	1013.2	1013.1	1013.5	1014.1	1014.7	1015.4	1015.5	1016.1
Low cloud cover		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Solar intensity (milliwatts/cm^2)		-	-	-	-	-	-	-	5.6	36.3	36.9	71.5	81.6	84.6	84	79	65.5	49	34.6	8	-	-	-	-	-
Shade temperature (°C)	24th	21.2	20.2	19.4	19.0	18.8	19.2	19.2	21.2	24.8	26.6	28.5	29.8	29.0	32.3	32.2	32.0	31.2	30.0	28.6	27.4	26.4	25.8	25.1	24.2
Wind speed (knots)	Aug.	02	02	02	03	02	02	01	05	07	03	08	03	05	09	10	12	12	14	13	14	08	09	07	05
Wind direction (degrees)	1962	060	270	240	240	220	210	330	230	260	280	290	310	350	030	020	060	050	040	040	060	070	080	070	060
Humidity (%)		86	89	88	91	92	92	92	88	75	71	64	54	57	46	41	44	48	54	61	67	75	76	79	82
Sea-level pressure (MBS)		1018.8	1018.4	1018.1	1018.0	1018.2	1018.5	1019.0	1019.6	1019.3	1019.7	1019.9	1019.4	1018.9	1018.6	1018.0	1017.7	1017.3	1017.7	1018.0	1018.0	1018.9	1019.5	1019.6	1019.7
Low cloud cover		1/8	1/8	1/8	Nil	2/8	2/8	2/8	3/8	1/8	2/8	7/8	6/8	5/8	3/8	4/8	3/8	2/8	Nil	2/8	2/8	1/8	Nil	Nil	Nil
Solar intensity (milliwatts/cm^2)		-	-	-	-	-	-	-	10	36.4	60.5/35	83.8/32	97/33.6	93.5/36	94	78	66	44.5	33.5	6.6	-	-	-	-	-
Shade temperature (°C)	25th	23.8	22.8	22.4	22.0	21.0	20.8	20.2	23.2	25.8	27.8	30.0	31.4	31.2	32.4	32.2	31.8	31.2	29.8	28.3	27.1	26.2	25.7	25.2	24.7
Wind speed (knots)	Aug.	05	06	07	04	04	03	03	06	12	13	12	08	08	08	13	13	15	16	15	10	11	10	08	08
Wind direction (degrees)	1962	090	060	070	090	060	090	110	110	140	120	110	140	060	090	060	070	050	060	060	060	060	070	090	100
Humidity (%)		83	88	88	92	91	93	94	85	73	62	50	43	38	39	39	40	42	50	57	63	71	73	74	77
Sea-level pressure (MBS)		1019.7	1019.3	1019.1	1018.9	1019.0	1019.0	1019.5	1019.8	1019.9	1020.3	1020.0	1019.8	1019.1	1018.6	1018.0	1017.4	1018.3	1017.0	1017.7	1018.1	1018.4	1018.8	1019.2	1019.4
Low cloud cover		Nil	Nil	Nil	Nil	Nil	1/8	1/8	1/8	1/8	1/8	2/8	2/8	3/8	4/8	4/8	2/8	1/8	1/8	1/8	1/8	1/8	Nil	Nil	Nil
Solar intensity (milliwatts/cm^2)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shade temperature (°C)	27th	23.4	23.2	22.9	22.0	21.6	21.0	20.8	23.2	25.1	27.0	29.2	31.2	32.2	32.8	33.2	32.6	32.8	30.0	29.2	27.2	26.2	25.3	24.2	23.4
Wind speed (knots)	Aug.	06	06	04	06	06	06	05	06	05	07	06	06	05	07	10	10	12	12	12	11	07	08	05	04
Wind direction (degrees)	1962	090	100	090	100	100	110	090	060	090	080	010	010	070	360	350	020	010	060	050	060	070	070	080	080
Humidity (%)		75	80	81	83	82	84	86	73	65	55	41	35	30	28	35	35	32	49	46	60	65	71	74	78
Sea-level pressure (MBS)		1017.9	1017.4	1017.0	1016.7	1016.3	1016.5	1016.9	1017.4	1018.1	1018.6	1018.6	1018.4	1017.8	1017.6	1016.8	1016.6	1016.3	1016.3	1016.5	1016.6	1017.0	1017.4	1017.8	1017.7
Low cloud cover		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1/8	2/8	3/8	3/8	1/8	1/8	1/8	Nil	Nil	Nil	Nil	Nil
Solar intensity (milliwatts/cm^2)		-	-	-	-	-	-	-	6.5	39	64	73.2	80.5	83.9	84.6	83.9	65.4	47.1	21	6	-	-	-	-	-
Shade temperature (°C)	28th	22.4	22.0	21.2	21.2	19.6	19.1	19.7	21.4	25.0	27.4	29.2	30.4	32.2	32.6	32.0	30.2	30.0	30.2	28.9	27.2	25.6	24.4	22.6	21.0
Wind speed (knots)	Aug.	04	02	02	02	02	02	02	03	05	08	06	07	06	11	12	07	10	10	10	07	04	05	02	02
Wind direction (degrees)	1962	100	130	040	030	040	030	030	070	090	060	050	030	260	030	030	350	020	010	010	030	060	060	050	060
Humidity (%)		83	79	82	82	85	85	84	80	64	51	39	32	26	30	32	38	33	36	46	53	64	70	75	83
Sea-level pressure (MBS)		1017.8	1017.4	1017.1	1017.0	1016.7	1016.9	1017.4	1018.0	1018.0	1018.7	1018.8	1018.6	1018.2	1017.8	1017.5	1017.0	1017.0	1017.0	1017.1	1017.3	1018.2	1018.9	1019.3	1019.4
Low cloud cover		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1/8	1/8	1/8	1/8	1/8	1/8	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Solar intensity (milliwatts/cm^2)		-	-	-	-	-	-	-	7.7	42.6	55.5	58	79	83.6	83.9	76.3	64	47.9	34.2	6	-	-	-	-	-
Shade temperature (°C)	15th	19.6	18.9	18.2	17.4	16.6	16.4	17.0	19.0	23.2	25.5	27.6	27.8	29.6	30.2	29.3	29.2	29.1	27.6	26.6	25.2	24.4	23.2	22.8	21.4
Wind speed (knots)	Sept.	Calm	0.2	01	Calm	Calm	Calm	Calm	02	06	05	05	07	11	07	12	12	12	12	12	10	06	05	05	02
Wind direction (degrees)	1962	Calm	140	140	Calm	Calm	Calm	Calm	160	180	130	120	060	060	040	040	050	070	060	060	060	060	070	090	100
Humidity (%)		85	87	90	90	92	92	91	83	68	62	54	53	49	42	49	52	51	57	61	68	70	74	78	84
Sea-level pressure (MBS)		1019.6	1018.8	1018.5	1018.1	1018.1	1018.3	1018.4	1018.0	1019.1	1019.1	1019.3	1018.8	1017.9	1017.1	1016.6	1016.7	1015.8	1015.8	1015.7	1015.7	1016.3	1016.6	1016.6	1016.9
Low cloud cover		Nil	Nil	Nil	Nil	Nil	Nil	Nil	1/8	Nil	Nil	1/8	5/8	5/8	5/8	5/8	5/8	3/8	1/8	Nil	Nil	Nil	Nil	Nil	Nil
Solar intensity (milliwatts/cm^2)		-	-	-	-	-	-	-	-	-	55	68.8	84.8	89.4	31.8	-	58.6	42.1	55	-	-	-	-	-	-

NOTE: Shade temperatures measured at 4ft above ground level.
Winds measured at 33 ft above ground level.

TABLE 1 (Contd.)

Quantity measured	Date	Time (local time = G.M.T. + 2 hrs)																						
		01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00
Shade temperature (°C)	19th	22.8	23.2	21.8	20.6	21.0	21.2	20.8	21.8	26.1	28.4	31.8	32.4	35.0	35.4	34.6	33.2	32.2	30.4	28.0	26.4	25.8	25.4	25.0	24.4
Wind speed (knots)	Sept.	05	06	05	06	05	05	02	02	06	04	02	07	05	10	14	15	13	15	16	17	10	10	08	05
Wind direction (degrees)	1962	060	080	060	030	050	040	070	090	120	150	280	060	030	050	010	040	040	040	040	050	060	070	070	060
Humidity (%)		76	65	77	80	79	86	88	80	49	42	36	32	22	27	37	49	58	57	75	84	80	85	86	81
Sea-level pressure (MBS)		1011.0	1011.0	1010.8	1010.8	1010.9	1011.0	1011.3	1011.9	1012.1	1012.5	1012.3	1012.1	1011.5	1011.2	1010.5	1010.1	1010.1	1010.2	1010.7	1011.2	1012.2	1012.9	1013.6	1013.7
Low cloud cover		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Solar intensity (milliwatts/cm^2)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shade temperature (°C)	20th	24.2	22.6	22.0	21.2	21.0	20.0	19.8	20.8	23.8	25.5	28.8	29.8	30.6	30.6	31.2	32.0	31.2	30.1	28.7	27.0	25.8	24.7	23.2	23.1
Wind speed (knots)	Sept.	03	03	03	02	Calm	Calm	Calm	Calm	03	05	05	05	05	05	07	06	07	07	06	06	06	03	02	Calm
Wind direction (degrees)	1962	050	070	090	090	Calm	Calm	Calm	Calm	209	250	100	210	030	330	340	360	060	040	060	050	030	040	060	Calm
Humidity (%)		88	93	95	96	95	97	98	95	90	82	69	63	59	62	58	48	60	55	67	76	81	87	92	92
Sea-level pressure (MBS)		1013.9	1013.9	1013.8	1013.7	1013.7	1013.7	1013.7	1014.2	1014.9	1014.7	1014.8	1014.6	1014.2	1014.1	1013.6	1013.5	1013.3	1013.5	1013.9	1014.3	1014.6	1015.5	1015.9	1016.1
Low cloud cover		Nil	Nil	Nil	Nil	3/8	6/8	6/8	6/8	6/8	7/8	4/8	2/8	1/8	1/8	1/8	1/8	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Solar intensity (milliwatts/cm^2)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

NOTE: Shade temperatures measured at 4 ft above ground level.
Winds measured at 33 ft above ground level

APPENDIX 2

THE FLIGHT RECORDER

by

R. S. Howell

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1 FLIGHT RECORDER

The flight recorder shown schematically in Fig.1 consists of a Dekko 16 mm camera, modified to single shot, which is controlled and operated by an electronic timing circuit. The camera photographs, through two 45° mirrors, the two instruments mounted above it, namely a temperature indicator and a clock, which are illuminated for the exposure.

2 TIMING AND SELECTOR UNIT

The circuit consists basically of a C.R. time constant and an emitter follower which operates, through a zener diode, two relays, a uniselector and the camera motor. (See Fig.2.)

The circuit supply voltage is stabilised at 16.8 volts by the three zener diodes D.1, D.2 and D.3. This voltage charges C.1 through R.2. The voltage on C.1 is impressed through the emitter follower TR.1, onto the zener diode D.4. At approximately 5.6 volts the diode breaks down and TR.2 conducts allowing relay A to energise. Relay A has four sets of contacts, three of which are used. A.1 provides a hold-on path for the relay, A.4 switches on the instrument lighting and A.3 switches positive volts onto the camera motor. The camera runs until SW.1 is made. This is a commutator switch operated by the camera motor. SW.1 completes an energising path for relay B. Relay B has four sets of contacts, all of which are used. B.3 short circuits C.1 reducing the volts across it to zero, B.2 provides a hold on path for the relay through SW.2, B.4 open circuits the coil of relay A causing the camera to stop, and B.1 switches volts onto the coil of the uniselector allowing it to operate once. In operating, the uniselector open circuits the energising coil of relay B through switch SW.2. Relay B de-energising allows the whole cycle of events to be repeated at a period governed by the time constant C.1 R.2.

Fig.3 shows the complete recorder mounted on anti-vibration mountings in a No.114 bomb tail. By unscrewing two knurled nuts, the whole unit can be withdrawn from the tail, and is shown in Fig.4.

3 TESTING

The unit has been tested to operate and give satisfactory photographs under vibration and also at an ambient temperature of 70°C for 1 hour. In flight, the space between bomb tail and recorder was packed with glass-wool to provide some heat insulation, but in fact, under the conditions available for the flights, this was not really necessary.

ATTACHED:

Drg. Nos. WE.R.3194-3195
Neg. Nos. 160,661

WE. R. 3194

T.N. WE. 13
APPENDIX 2
FIG. 1.

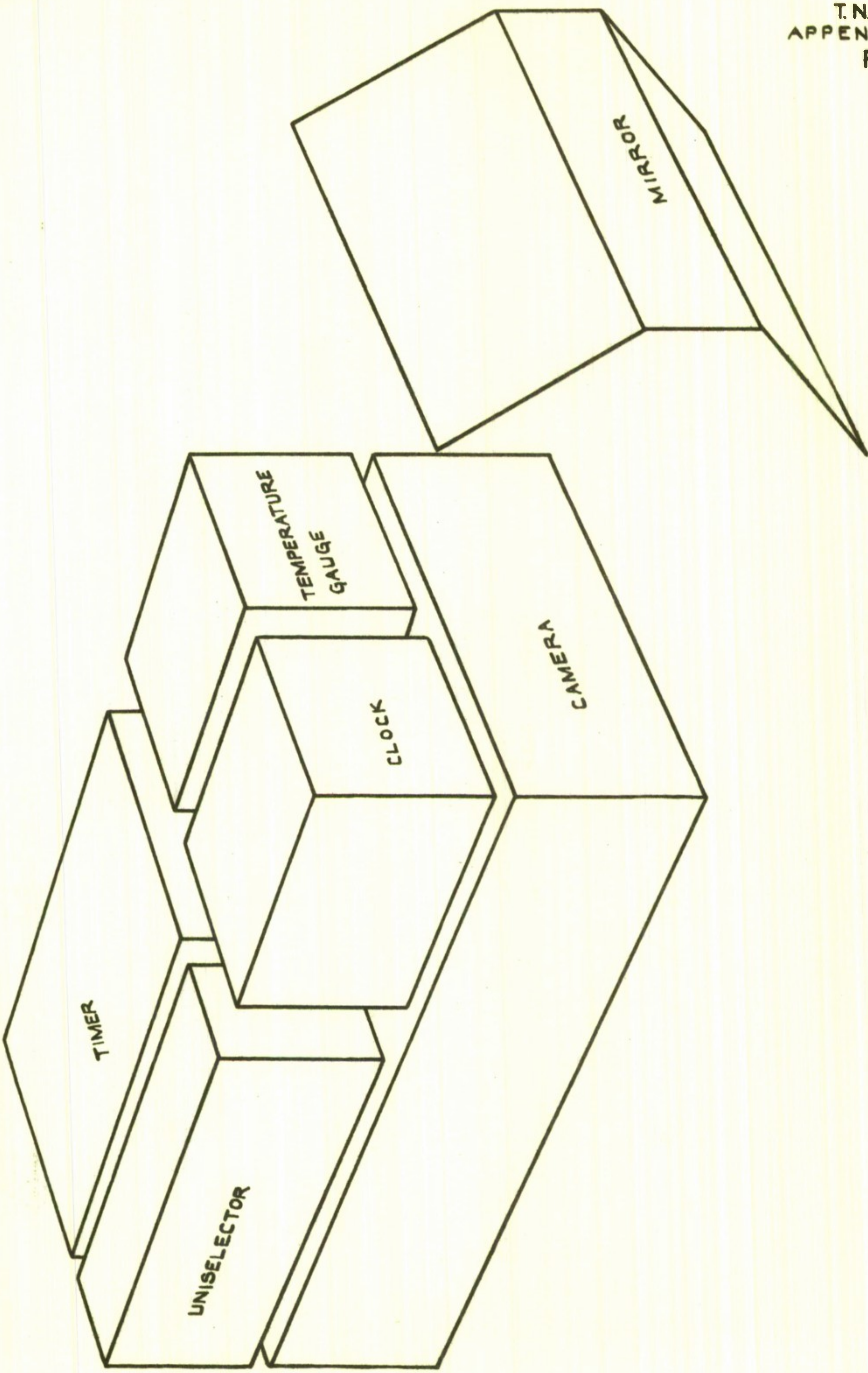


FIG. 1. AUTO-OBSERVER SCHEMATIC DIAGRAM.

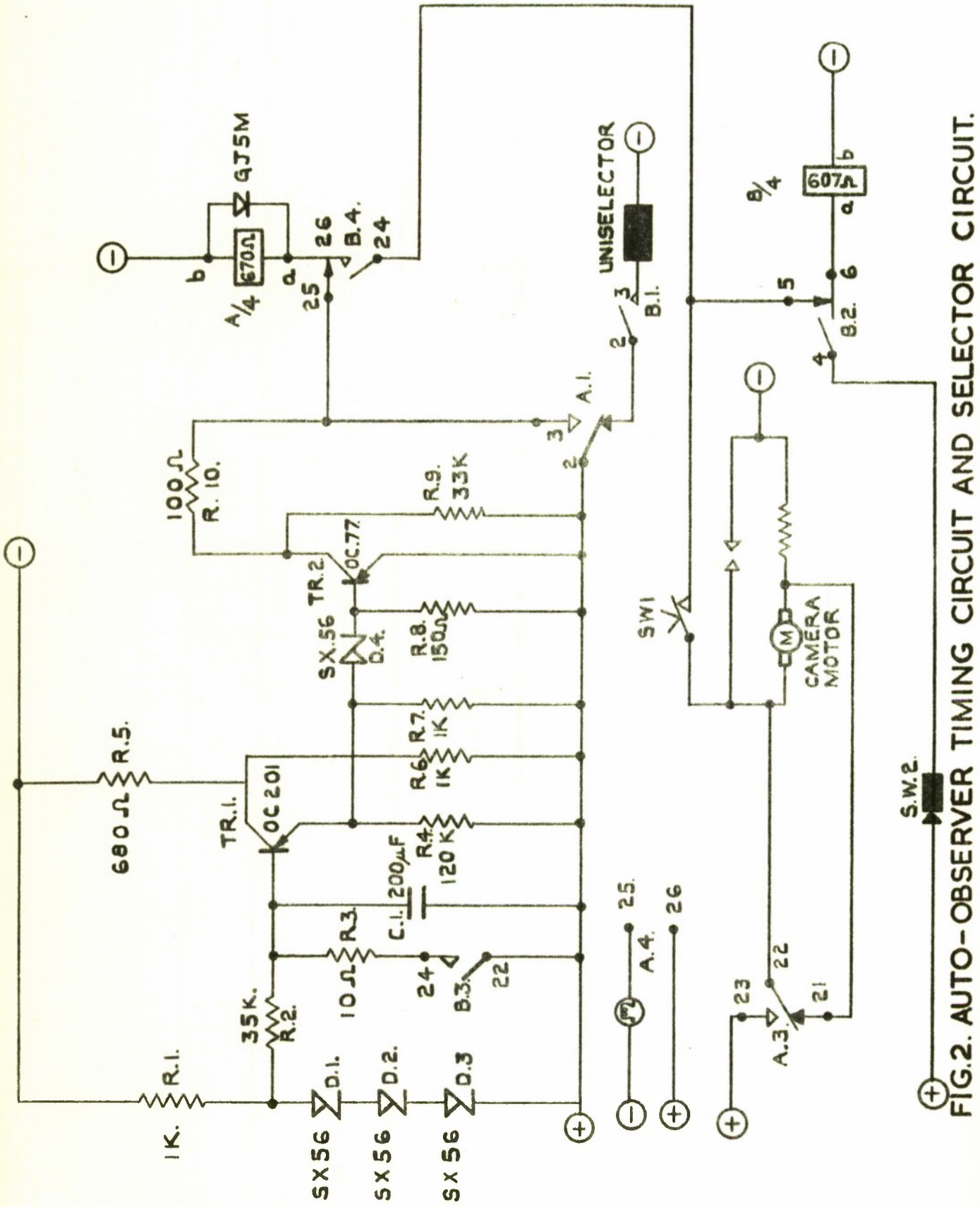


FIG.2. AUTO-OBSERVER TIMING CIRCUIT AND SELECTOR CIRCUIT.

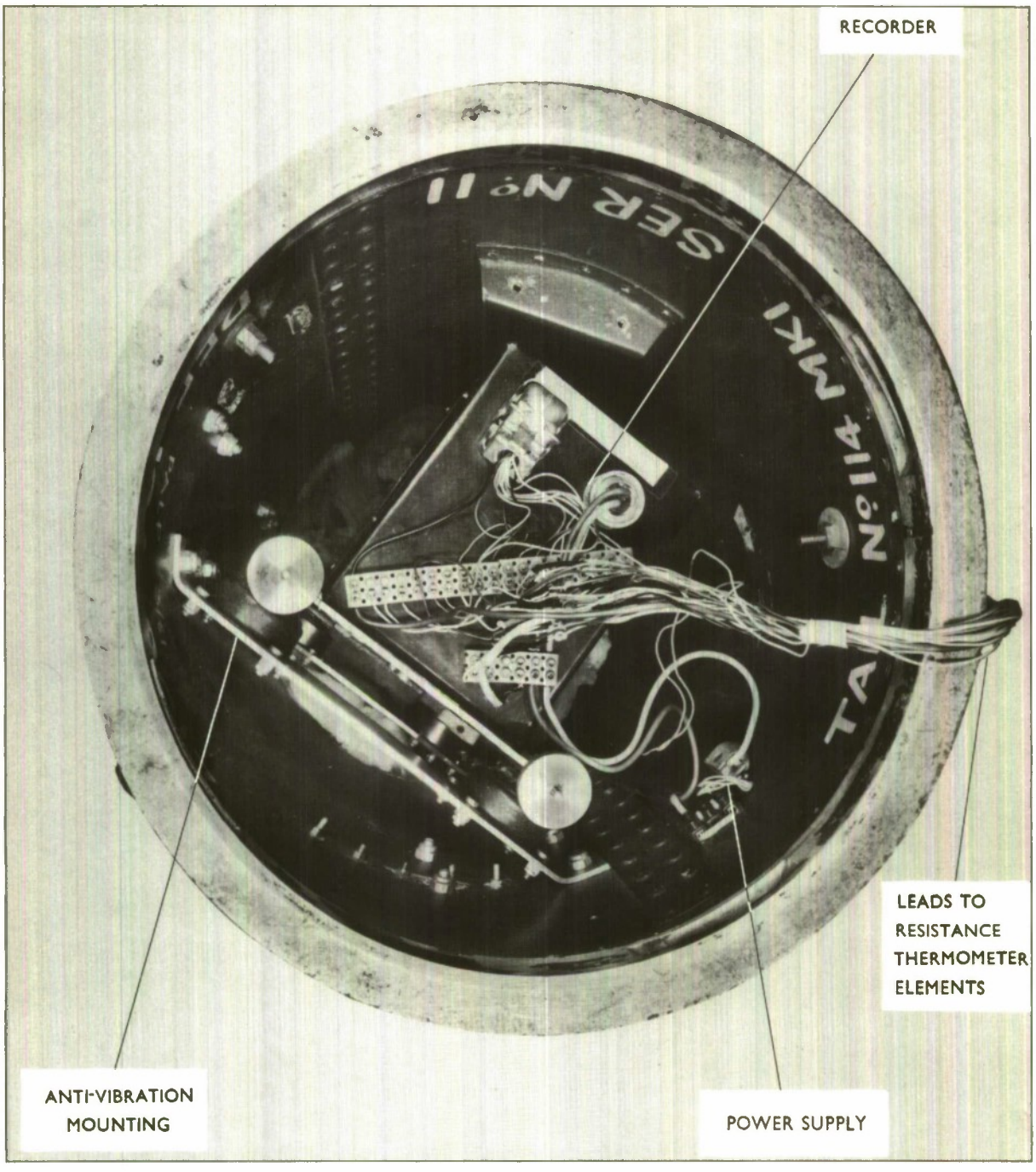


FIG.3. FLIGHT RECORDER MOUNTED IN BOMB TAIL

TABLE 1

Bomb temperatures for ground trial No.1 1000 lb Mk.10 bomb, nose pointing to south

	Times (G.M.T. + 2 hrs)														
	06.00	07.00 Daylight 06.30	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00 Darkness
Gauge No.1		-	-	-	-	-	-	-	-	-	-	-	-	-	-
2		20°C	20.2°C	26.6°C	34°C	39.1°C	42°C	43.6°C	43.8°C	44.1°C	44.4°C	44°C	42.4°C	38.6°C	35.6°C
3		20	20	21.7	27.2	31.2	35	37.7	39.2	40.2	40.6	41	41	39.2	37.2
4		20	20.6	24.2	30.4	36.5	41.8	47.2	51	54.2	56	53	44.8	38.6	35
5		20	20	22.6	27.9	33.2	37.8	42.6	46.6	49.8	51.2	51.4	45.6	40.1	36.6
6		20	20	21.2	24.4	29	33	37.8	41.4	44.6	47.2	48.2	46.7	42.2	39.2
7		20	20	22.4	27.8	31.4	35.2	37.5	39.4	40.6	42.2	42.2	40.2	36	33.9
8		20	20	21.4	26	29.6	32.8	35.8	38	40.2	41.8	42.4	41.4	38.5	36
9		20	20	20	22.4	23.6	28.6	31	33.8	36.1	38.1	39.6	40	38.6	36.6
10		20	21.5	34.4	43.1	46.2	48	47.8	46.6	45.4	44.4	42.4	40.4	36.1	32.6
11		20	20.8	28.5	35.8	39.6	41.8	42.4	42.8	41.8	41.8	41	39.4	36.4	33
12		20	20.2	22.2	28.1	31.8	35	36.4	37.4	37.8	38.2	38.4	37.9	36.4	34.4
13		20	21.6	25.6	31.4	36.6	42	47.6	52.6	56.4	58.4	57.8	44.1	37.6	33.6
14		20	20	23.2	27.2	31.2	36.4	40	45	48.4	50.8	51.4	44	38.8	35
15		20	20	20.6	23.7	27.2	30.6	35.2	39.2	41.8	45	46.8	44.7	40.4	37.2
16		20	20	23.2	27.6	30.4	32.6	34.4	36.4	37.8	39.6	40.4	38	35.4	33
17		20	20	21.8	26	28.6	30.8	32.8	35	36.8	38.4	39.5	37.8	35.2	32.8
18		20	20	20	21.9	24.3	26.5	28.3	30.3	31.3	33.5	35.3	35.4	34.4	32.9
22		-	-	-	-	-	-	-	-	-	-	-	-	-	-
23		20	20.2	29.2	35.4	37.4	39.8	40.6	42.4	42.6	42.6	40.8	35	31	28

Bomb skin:- Nose, gauges 1,4,7 Rear, gauges 10,13,16 (upper, portside) Gauges 1 and 22 inoperative.
Surface of filling:- Nose, gauges 2,5,8 Rear, gauges 11,14,17 (upper, starboard side)
3 cms into filling:- Nose, gauges 3,6,9 Rear, gauges 12,15,18 (bottom)
V.T. fuze:- Power unit, gauge 22 Amplifier, gauge 23

Met. conditions August 22nd 1962.

Solar radiation (milliwatts/cm^2)	-	5.6	36.3	36.9	71.5	81.6	84.6	84	79	65.5	49	34.6	8	-
Shade temperature (°C)	22.4	21.4	22.4	30.0	31.4	33.2	34.6	35.0	35.9	35.8	35.0	33.4	30.6	28.6
Cloud coverage						Nil cloud all day								

TABLE 2

Bomb temperatures for ground trial No.2. 1000 lb Mk.10 bomb, nose pointing to east

	Times (G.M.T + 2 hrs)																				
	06.00 Daylight 06.30 °C	07.00 °C	08.00 °C	09.00 °C	10.00 °C	11.00 °C	12.00 °C	13.00 °C	14.00 °C	15.00 °C	16.00 °C	17.00 °C	18.00 °C	19.00 °C	20.00 Dark-ness °C	21.00 °C	22.00 °C	23.00 °C	24.00 °C	01.00 °C	02.00 °C	03.00 °C	04.00 °C
Gauge No.1		18	18.5	19.4	26	29.5	-	-	-	-	-	-	-	-	-	26	24.6	24	23	22.4	21.4	20.4	19.8
2		18	18.5	19.3	23.5	27.5	29.5	32.8	36.3	37	36.5	35.5	33	31	28.5	26.9	25.9	24.7	24.1	23.5	22.5	21.5	20.5
3		18	18	18	20	22.5	25.5	27.8	31	32.6	33.5	33.5	32.6	31.5	29	28	26.6	25.8	24.8	23.5	22.8	22	21
4		18	18.6	19.5	29.5	33	38.5	42.4	44	44.5	41.8	37.8	33	30.3	28	26	25	24	23	22.4	21.4	20.6	20
5		18	19	19	26.5	29	35	38	41	42	40.8	39	35	31.5	28.5	26.9	25.5	24.9	23.9	22.9	21.9	21.5	20.5
6		18	18	18.5	22	25.5	30	33	36.2	38	38.5	37.6	34.6	33.2	30.2	28.5	27.3	26	25	24	23	22.2	21.8
7		18	18.3	19	22.5	25.5	28.5	31	33.5	34.5	34.3	33.3	31.3	30.5	28.9	26.5	25.5	25	24	23.5	22.7	21.9	21.5
8		18	18	18.4	21	24	27.5	29.6	32	33.5	33.8	33	33	31	29	27.2	25.8	25	23	23	22	21.4	20.8
9		18	18	18	18.5	21.5	24.5	26.3	28.3	30.1	31.3	31.3	32.3	30.5	29.5	27.5	26.3	25.3	24.5	23.5	22.5	21.5	20.9
10		18	19.2	20.4	26	29.5	33.5	35.6	38	38.8	38.5	36.6	33	30	27	25.4	24.4	23.6	23	22	21.2	20	19.7
11		18	19	19.5	23	26.5	29.5	32	34.6	36	36.4	35	32.8	30.5	28	26.3	25.6	24.5	23.8	23	22.4	21.6	20.4
12		18	18	18	19.5	22	25	26.6	28.8	30.4	31.6	32	31	30	28	26.8	26	24.8	24	23.4	22.4	21.8	21
13		18	19.5	21.3	30.5	34.7	40.5	44.5	45.5	47.5	45.1	40.1	33.9	30.5	27.5	26	25	24	23.5	22.5	21.5	20.7	20.1
14		18	18.2	19.4	25.5	28	34	37	40	42	40.8	38	34	31.8	28.2	27	26	25	24	23	22.4	21.8	20.6
15		18	18	18.2	22	24.6	28.5	31	35.2	37.5	37.8	37	34	32.8	30	28	27	25.5	24.4	23.5	22.8	22	21.2
16		18	18	18.4	21	23.5	26	28	30.4	31.8	32	31	29.8	28	26.5	25.5	24.5	23.8	23	22.5	21.8	21.4	20.4
17		18	18	18	20	22.6	25	27.2	29	30.5	31	30.6	29	28.5	27	25	24	23	22.3	22.8	22	21.5	20.8
18		18	18	18	18	19	21	23	25	26.4	27	27.4	27.5	27.5	26.6	26	24	24.4	23.5	23	22.4	21.5	21
Solar radiation (milliwatts /cm²)	-	10	36.4	35 min. 60.5 max.	32 min. 83.8 max.	33.6 min. 97 max.	36.0 min. 93.5 max.	94	78	66	44.5	33.5	-	6.6	-	-	-	-	-	-	-	-
Shade temperature (°C)	19.2	21.2	24.8	26.6	28.5	29.8	29.0	32.3	32.2	32.0	31.2	30.0	28.6	27.4	26.4	25.8	25.1	24.2	23.8	22.8	22.4	22.0	
Cloud coverage	2/8	3/8	1/8	2/8	7/8	6/8	5/8	3/8	4/8	3/8	2/8	Nil	2/8	2/8	1/8	Nil	Nil	Nil	Nil	Nil	Nil	Nil	

Bomb skin : Nose, gauges 1, 4, 7 Rear, gauges 10, 13, 16 No V.T. fuze fitted
Surface of filling: Nose, gauges 2, 5, 8 Rear, gauges 11, 14, 17
3 cms into filling: Nose, gauges 3, 6, 9 Rear, gauges 12, 15, 18 Gauge 1 partly inoperative

Met. conditions - 24-25th August, 1962

TABLE 3

Bomb temperatures for ground trial No.3. 1000 lb Mk.10 bomb, nose pointing to east

	Times (G.M.T. + 2 hrs)																				
	06.00 Daylight 06.30 °C	07.00 °C	08.00 °C	09.00 °C	10.00 °C	11.00 °C	12.00 °C	13.00 °C	14.00 °C	15.00 °C	16.00 °C	17.00 °C	18.00 °C	19.00 °C	20.00 Dark-ness °C	21.00 °C	22.00 °C	23.00 °C	24.00 °C	01.00 °C	02.00 °C	03.00 °C	04.00 °C
Gauge No.1		21	21.2	22	29.4	33.8	38.2	41.4	43.2	44.2	43	41.8	40.2	38	35.4	33.2	32.2	31.2	30.2	29.2	28.2	27.2	24.2
2		21	21.2	21.6	28.6	30.4	34.2	37.8	39.8	41.2	41.2	40.6	39.8	38	35.4	34	32.7	31.4	31	30	29.2	28.2	27
3		21	21	21	23	25.9	29.8	32	35	37	38	38	38.2	37.8	36	35	33.9	32	31.2	30	29.6	29	26.8
4		21	21.2	22.5	34.8	40.8	46	49.6	50	50.2	47.2	43.4	41	38	35.2	33.6	32.2	31.2	30.2	29.6	29	27.6	26.8
5		21	21.8	22.2	30.5	36	40.8	45	46	47.4	46	44.8	42	40	36.4	35.4	34	32	31.6	31	30	29.2	28
6		21	21	21	25.8	29.8	35	39.4	41.8	42.8	43.2	42.8	41.6	40.2	37.2	36	34.7	33	32.2	30.8	30	28.8	28.6
7		21	21	21.8	26.2	29.6	33.6	36.6	37.6	39	39	38.6	38.2	37	35.2	33.6	32.6	31.6	30.6	29.6	28.6	28	27.4
8		21	21	21.2	23	26.4	29.8	33.8	35.8	38	38.4	38	38.2	39.4	-	-	40	39	-	31	29	27	25.6
9		21	21	21.8	21.6	24.2	26.8	30	33	35.4	36.4	37	37.4	40	-	-	40.4	40.2	-	32.4	28.8	28.2	26.6
10		21	21.4	23.2	29.4	33	37.2	40.4	42.6	44.4	43.2	43	41.6	38.2	34.8	33	31.4	30.4	29.4	28.4	27.4	26.4	25.4
11		21	21	22.2	25.8	29	31.8	35.8	37.8	39.8	39.8	40	29.8	37.2	34.8	32.8	31.8	30.8	29.8	28.8	28	27.2	26.6
12		21	21	21	22.8	25	27.4	30.4	32.9	34.8	36.1	36.4	36.8	36.6	34.8	34.2	32.2	31.4	30.4	29.6	28.6	28.2	27.2
13		21	22	25	35.4	41.8	48	52	53	53.8	60.8	57	42	38.4	35	33.6	32	31.4	30.2	29.4	28.2	27.6	26.2
14		21	21.2	22.8	29.6	34.4	39.4	44.4	46.4	47.9	46.4	44.4	41.6	38.4	35.6	34.4	33.4	31.4	30.6	29.4	29.4	28.4	27
15		21	21	21	24.8	28.2	32.8	37.6	39.8	41.8	42.4	42	40.8	38.8	36	35	33	32	30.2	30	29	28.2	27
16		21	21	21.4	24.2	26.6	29.8	33.2	35.2	36.4	36.8	36.8	36.2	35	33.2	32.2	31.2	29.8	29.2	28.2	27.4	26.6	25.6
17		21	21	21.4	23	25.8	28.6	31.6	33.4	35.6	35.8	36	35.6	35	33.8	32	31	29.2	29.8	29	28	27	26
18		21	21	21	21	22.8	24.4	27	29	30.5	31.4	32	32.2	32.8	32	31.6	31	30	29.8	29	28	27.8	27
Solar radiation (milliwatts /cm^2)	-	6.5	39	64	73.8	80.5	83.9	84.6	83.9	65.4	47.1	21	6	-	-	-	-	-	-	-	-	-
Shade temperature (°C)	20.2	23.2	25.1	27	29.2	31.2	32.2	32.8	33.2	32.6	32.8	30	29.2	27.2	26.2	25.2	24.2	23.4	22.4	22	21.2	21.2
Cloud coverage	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1/8	2/8	3/8	3/8	1/8	1/8	1/8	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Bomb skin : Nose, gauges 1, 4, 7, Rear, gauges 10, 13, 16 No V.T. fuze fitted
Surface of filling: Nose, gauges 2, 5, 8, Rear, gauges 11, 14, 17,
3 cms into filling: Nose, gauges 3, 6, 9 Rear, gauges 12, 15, 18

Met. conditions - 27-28th August, 1962

TABLE 4

Bomb temperatures for ground trial No.4. 1000 lb Mk.10 bomb on Buccaneer pylon, nose pointing west

	Time (G.M.T. + 2 hrs) Sept.15th 1962									
	09.30	10.00	10.30	11.00	11.30	12.00	12.30	13.00	13.30	14.00
Gauge No.1	23.5°C	24.3°C	25.3°C	25.1°C	25.7°C	25.8°C	25.7°C	26.9°C	26.9°C	27.3°C
2	23.5	24.1	23.9	25.3	25.7	25.7	26.3	26.3	25.9	-
3	23.5	23.5	23.5	24.5	25.1	25.1	25.5	25.5	25.9	-
4	23.5	24.1	24.5	24.5	26	26	26.9	27.1	27.9	27.9
5	23.5	23.7	24.1	24.5	25.5	25.3	25.9	26.1	27	27
6	23.5	24.1	24.1	24.3	25.1	24.9	25.3	25.3	26.1	26.1
7	-	-	-	-	-	-	-	-	-	-
8	23.5	23.9	24.9	24.7	25.9	25.9	26.3	26.3	27.3	26.9
9	23.5	23.9	24.7	24.7	25.5	25.9	25.9	25.9	26.5	26.3
10	23.5	24.3	24.3	24.3	24.7	24.7	24.9	25.1	25.1	25.1
11	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5
12	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5

Bomb case:- gauges 1, 4, 8
Surface of filling: gauges 2, 5, 9
3 cms into filling: gauges 7, 11, 12

Met. conditions	September 15th, 1962									
Solar radiation (milliwatts/cm^2)	38	55	64.5	68.8	37.0	84.8	85.4	89.4	-	31.8
Shade temperature (°C)	-	25.5	-	27.6	-	27.8	-	29.6	-	30.2
Wind speed (kts)	-	5	-	5	-	7	-	11	-	7
Wind direction	-	130	-	120	-	060	-	060	-	040
Cloud coverage	-	Nil	-	1/8	-	5/8	-	5/8	-	5/8

TABLE 5

1000 lb Mk.10 bomb carried in Buccaneer bomb bay. Temperatures obtained during flight at Idris, September 20th 1962

Gauge No.	Time (minutes) 0	5	10	15	20	25	30	35	40
	Temperature rises (°C)								
1	0	4	7.8	10.7	13.3	15.8	17.5	17.5	18.1
2	0	1.2	3.1	4.2	7.9	9.5	10.6	11.8	12
3	0	0.2	0.5	0.7	1.1	1.9	2.8	3.7	3.9
4	0	2.7	6.7	8.9	12.7	14.7	16.6	17.5	17.8
5	0	0.9	2.7	4	6.5	8.8	10.3	10.9	11.6
6	0	0	0.3	0.8	0.9	1.5	2.2	2.9	3.5
8	0	4.1	7.1	10.7	13	16	17.8	18.4	18
9	0	1.5	3.2	7.1	8.4	9.9	11.2	12.1	12.4
10	0	0.4	0.7	0.6	1.3	2	3.1	3.9	4
11	0	13	21.6	27.4	30.9	33.5	34.6	35.2	35.2
12	0	9.5	15.6	20.6	24.1	26.3	28.8	30	31
	Mean initial temperature of whole bomb 32°C								
	Temperatures obtained (°C)								
1	32	36	39.8	42.7	45.3	47.8	49.5	49.5	50.1
2	32	33.2	35.1	36.2	39.9	41.5	42.6	43.8	44
3	32	32.2	32.5	32.7	33.1	33.9	34.8	35.7	35.9
4	32	34.7	38.7	40.9	44.7	46.7	48.6	49.5	49.8
5	32	32.9	34.7	36	38.5	40.8	42.3	42.9	43.6
6	32	32	32.3	32.8	32.9	33.5	34.4	34.9	35.5
8	32	36.1	39.1	42.7	45	48	49.8	50.4	50
9	32	33.5	35.2	39.1	40.4	41.9	43.2	44.1	44.4
10	32	32.4	32.7	32.6	33.3	34	35.1	35.9	36
11	32	45	53.6	59.4	62.9	65.5	66.6	67.2	67.2
12	32	41.5	47.6	52.6	56.1	58.3	60.8	62	63
	Mean temperatures (°C)								
Bomb skin	32	35.6	39.2	42.1	45	47.5	49.3	49.8	50
Surface of filling	32	33.2	35	37.1	39.6	41.4	42.7	43.6	44
3 cms into filling	32	32.2	32.5	32.7	33.1	33.8	34.7	35.5	35.8
V.T. fuze power unit	32	45	53.6	59.4	62.9	65.5	66.6	67.2	67.2
V.T. fuze amplifier	32	41.5	47.6	52.6	56.1	58.3	60.8	62	63

Flight conditions

Height 500 ft
Speed M = 0.81
Take off - 12.00 hrs
Ambient temperature 30°C

Bomb case	gauges 1, 4, 8
Surface of filling	gauges 2, 5, 9
3 cms into filling	gauges 3, 6, 10
V.T. fuze power unit	gauge 11
V.T. fuze amplifier	gauge 12

Gauge 7, reference point, no recording

Bomb in forward starboard position (doors open) or forward port position when doors closed.

Temperatures of E.R.U. cartridges did not exceed 65°C.

TABLE 6

1000 lb Mk.10 bomb carried on Buccaneer port inboard pylon. Temperatures obtained during flight at Idris, September 19th, 1962

Gauge No.	Time (minutes) 0	5	10	15	20	25	30	35	40
	Temperature rises (°C)								
1	0	12.5	24.7	27	28	28.4	27.8	28.7	27
2	0	3.4	9.5	14.4	18.2	20.4	21.5	21.3	21.6
3	0	0.3	0.6	1.8	3.5	4.5	6.8	8.6	10.1
4	0	12	24.3	26.4	27	27.6	27.6	27.5	26.4
5	0	2.2	8.6	14	16.8	18.2	19.9	21.7	21.2
6	0	0.1	0.3	1.6	2.9	5	6.4	8	9.6
8	0	14.5	26	30.6	30.8	31	31	30.8	28.8
9	0	4.6	10.4	15.1	19	21.4	23.7	23	22.9
10	0	0.5	2.2	2.6	5.6	7	9	10.4	12.1
11	0	16.1	28.5	33	33.7	33.5	34	33.5	28
12	0	14	26	31	32	32.5	32.3	32	30
	Mean initial temperatures: Bomb case, 32°C, surface of filling 30°C, 3 cms into filling 28°C, V.T. fuze 32°C.								
	Temperatures obtained (°C)								
1	32	44.5	56.7	59	60	60.4	59.8	60.7	59
2	30	33.4	39.5	44.4	48.2	50.4	51.5	51.3	51.6
3	28	28.3	28.6	29.8	31.5	32.5	34.8	36.6	38.1
4	32	44	56.3	58.4	59	59.6	59.6	59.5	58.4
5	30	32.2	38.6	44	46.8	48.2	49.9	51.7	51.2
6	28	28.1	28.3	29.6	30.9	33	34.4	36	37.6
8	32	46.5	58	62.6	62.8	63	63	62.8	60.8
9	30	34.6	40.4	45.1	49	51.4	53.7	53	52.9
10	28	28.5	30.2	30.6	33.6	35	37	38.4	40.1
11	32	48.1	60.5	65	65.7	65.5	66	65.5	60
12	32	46	58	63	64	64.5	64.3	64	62
	Mean temperatures (°C)								
Bomb case	32	45	57	60	60.6	61	60.8	61	59.4
Surface of filling	30	33.4	39.5	44.5	48	50	51.7	52	51.9
3 cms into filling	28	28.3	29	30	32	33.5	35.4	37	38.6
V.T. fuze power unit	32	48.1	60.5	65	65.7	65.5	66	65.5	60
V.T. fuze amplifier	32	46	58	63	64	64.5	64.3	64	62
	Theoretical temperatures (°C)								
3 cms into filling	28	30.1	32.1	33.6	34.5	36.5	38.2	39	39.9

Flight conditions

Height 500 ft
Speed M = 0·81
Take-off 15.00 hrs
Ambient temperature 30°C

Bomb case	gauges 1, 4, 8
Surface of filling	gauges 2, 5, 9
3 cms into filling	gauges 3, 6, 10
V.T. fuze power unit	gauge 11
V.T. fuze amplifier	gauge 12
Gauge 7, reference point,	no recording.

TABLE 7

Calculated flight limitations for V.T. fuzes Nos.906 and 907 when their temperatures must not exceed 70°C

Sea level temperature °C	Limiting Mach number for heights of:- 0	2000 ft	5000 ft	10,000 ft	20,000 ft	30,000 ft	Tropopause
-26	1.45	1.45	1.45	1.55	1.7	1.85	2.15
-20	1.4	1.4	1.45	1.5	1.65	1.85	2.15
-15	1.35	1.4	1.4	1.45	1.65	1.8	2.1
-10	1.3	1.3	1.3	1.45	1.6	1.75	2.05
- 5	1.25	1.3	1.3	1.4	1.55	1.75	2.0
0	1.2	1.2	1.25	1.35	1.5	1.7	1.95
5	1.15	1.2	1.2	1.3	1.5	1.65	1.9
10	1.1	1.1	1.2	1.25	1.45	1.65	1.85
15	1.0	1.1	1.15	1.25	1.4	1.6	1.8
20	1.0	1.0	1.1	1.2	1.4	1.6	1.75
25	0.9	1.0	1.1	1.15	1.35	1.55	1.75
30	0.9	1.0	1.05	1.15	1.35	1.55	1.75
35	0.8	0.95	1.0	1.1	1.35	1.5	1.7
40	0.7	0.95	1.0	1.1	1.3	1.45	1.7
45	0.7	0.9	0.95	1.05	1.3	1.45	1.65
50	0.6	0.9	0.9	1.05	1.25	1.4	1.6

NOTE: (1) For speeds in excess of the above, temperature limits will be exceeded for any flight in excess of 10 minutes duration.

(2) Values above are rounded to the nearest 0.05M.

TABLE 8

Calculated flight limitations for 1000 lb bombs when the bomb filling temperature must not exceed 80°C at a depth of 3 cms after 40 minutes flight

Sea level temperature °C	Limiting Mach number for heights of:- 0	2000 ft	5000 ft	10,000 ft	20,000 ft	30,000 ft	Tropopause
-26	2.5	2.5	2.5	2.6	2.75	2.85	3.15
-20	2.4	2.4	2.4	2.55	2.7	2.8	3.1
-15	2.3	2.3	2.35	2.5	2.65	2.8	3.05
-10	2.25	2.25	2.3	2.4	2.6	2.75	3.0
-5	2.2	2.2	2.2	2.35	2.55	2.75	2.95
0	2.1	2.1	2.15	2.3	2.5	2.7	2.9
5	2.0	2.05	2.1	2.25	2.45	2.7	2.83
10	1.95	2.0	2.05	2.2	2.4	2.65	2.8
15	1.85	1.9	1.95	2.15	2.35	2.65	2.75
20	1.8	1.85	1.9	2.1	2.3	2.6	2.75
25	1.75	1.8	1.85	2.0	2.25	2.6	2.7
30	1.65	1.75	1.8	1.95	2.2	2.55	2.7
35	1.6	1.65	1.75	1.9	2.15	2.5	2.65
40	1.5	1.6	1.7	1.85	2.1	2.5	2.65
45	1.45	1.5	1.6	1.8	2.05	2.45	2.65
50	1.35	1.45	1.55	1.75	1.0	2.4	2.6

NOTE: (1) These limitations apply only to the bomb itself, or one with fuzes inserted in fuze wells within the bomb nose or tail. They do not apply to a V.T. fuze external to the bomb.

(2) Initial bomb temperatures assumed (see Ref.4):-

Sea level temp.	Initial bomb temp.
-26 to -10°C	-20°C
- 9.9 to +10°C	0°C
10.1 to 30°C	20°C
30.1 to 50°C	30°C

(3) Values are rounded to the nearest 0.05M.

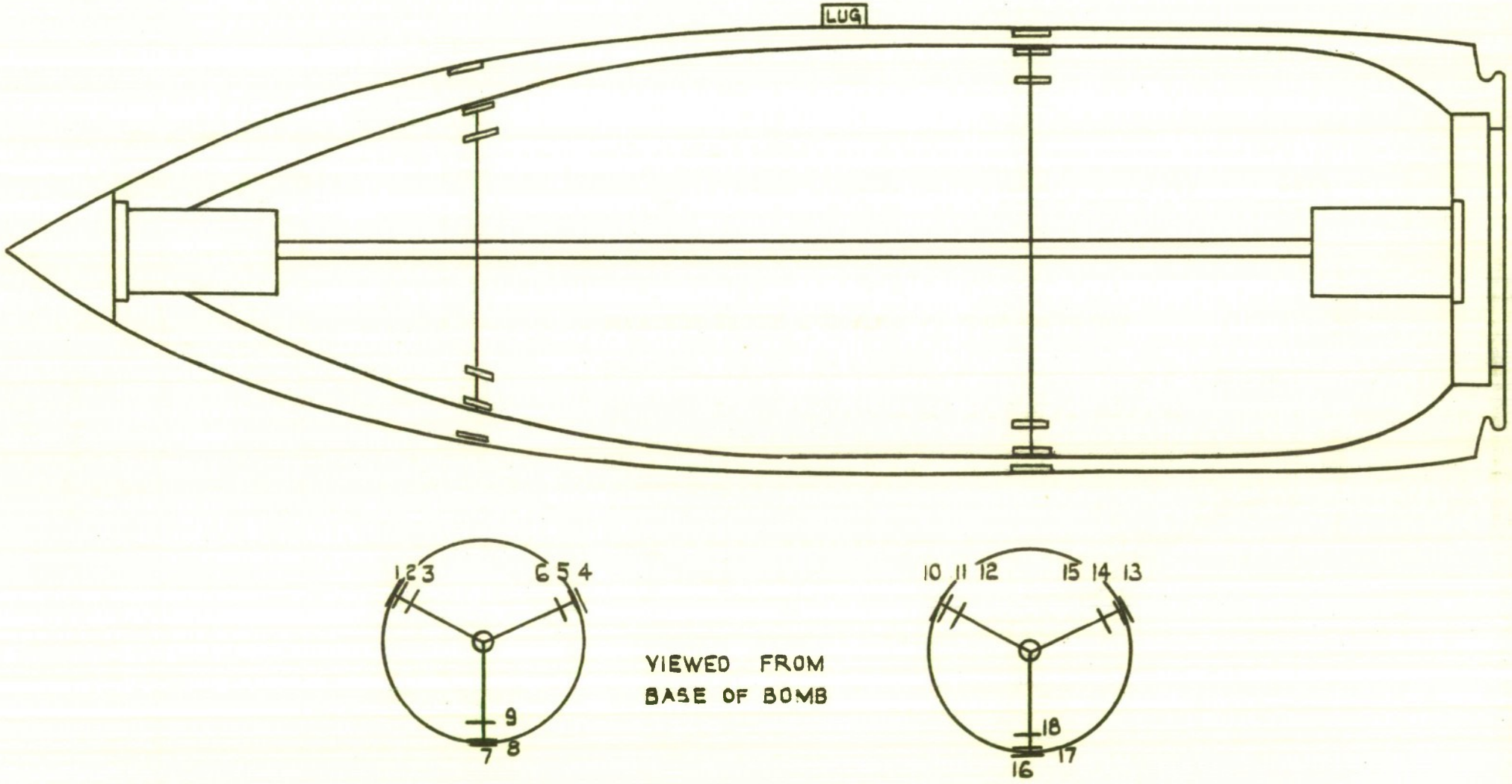


FIG.1. RESISTANCE THERMOMETER ELEMENTS IN BOMB.

T.N. WE. 13
FIG.1.

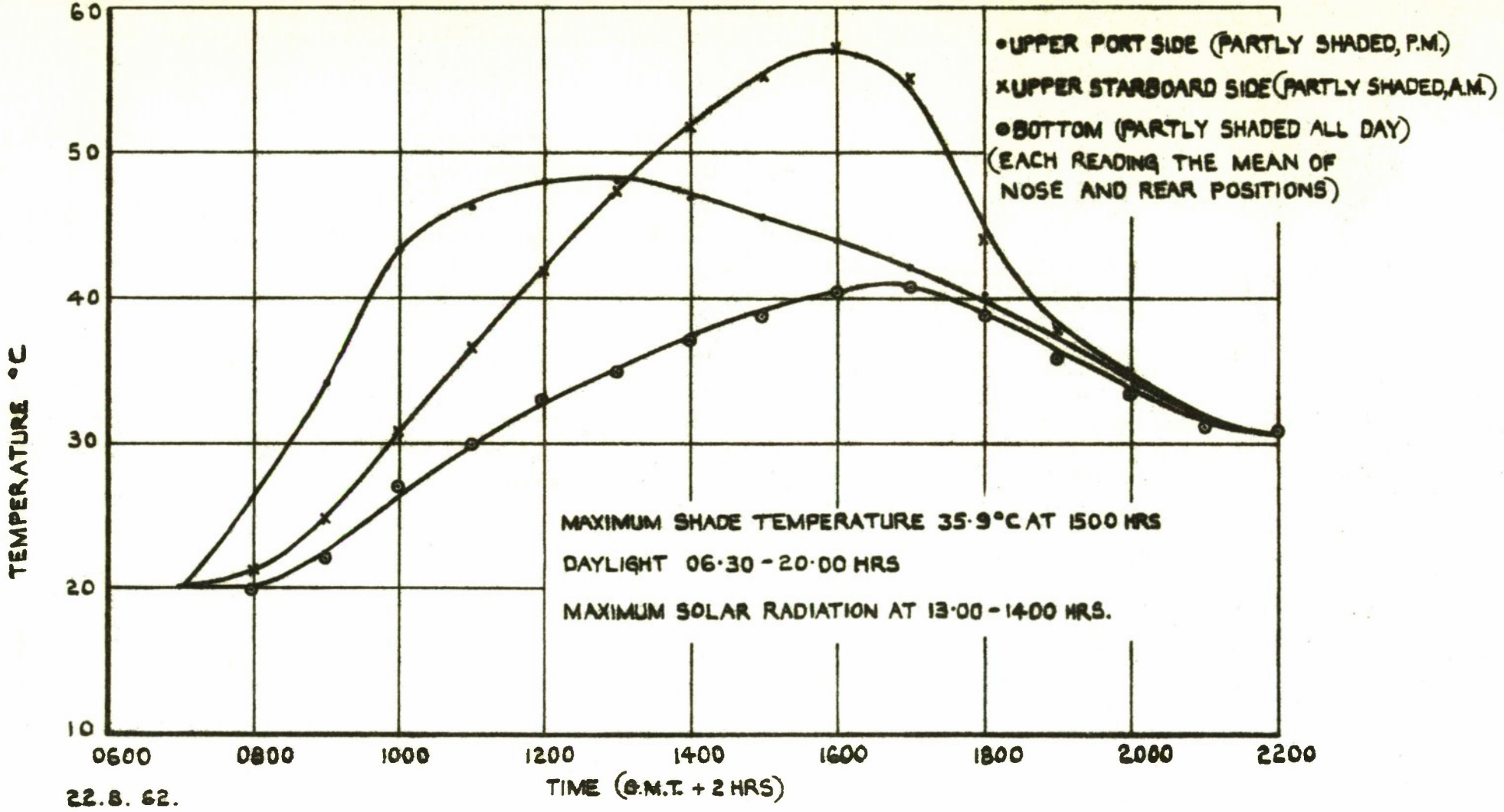


FIG. 2. 1000 LB. MK. 10 BOMB ON GROUND. TRIAL No. 1. TEMPERATURES RECORDED ON BOMB SKIN. BOMB NOSE TO SOUTH.

T.N. WE.13. FIG. 2.

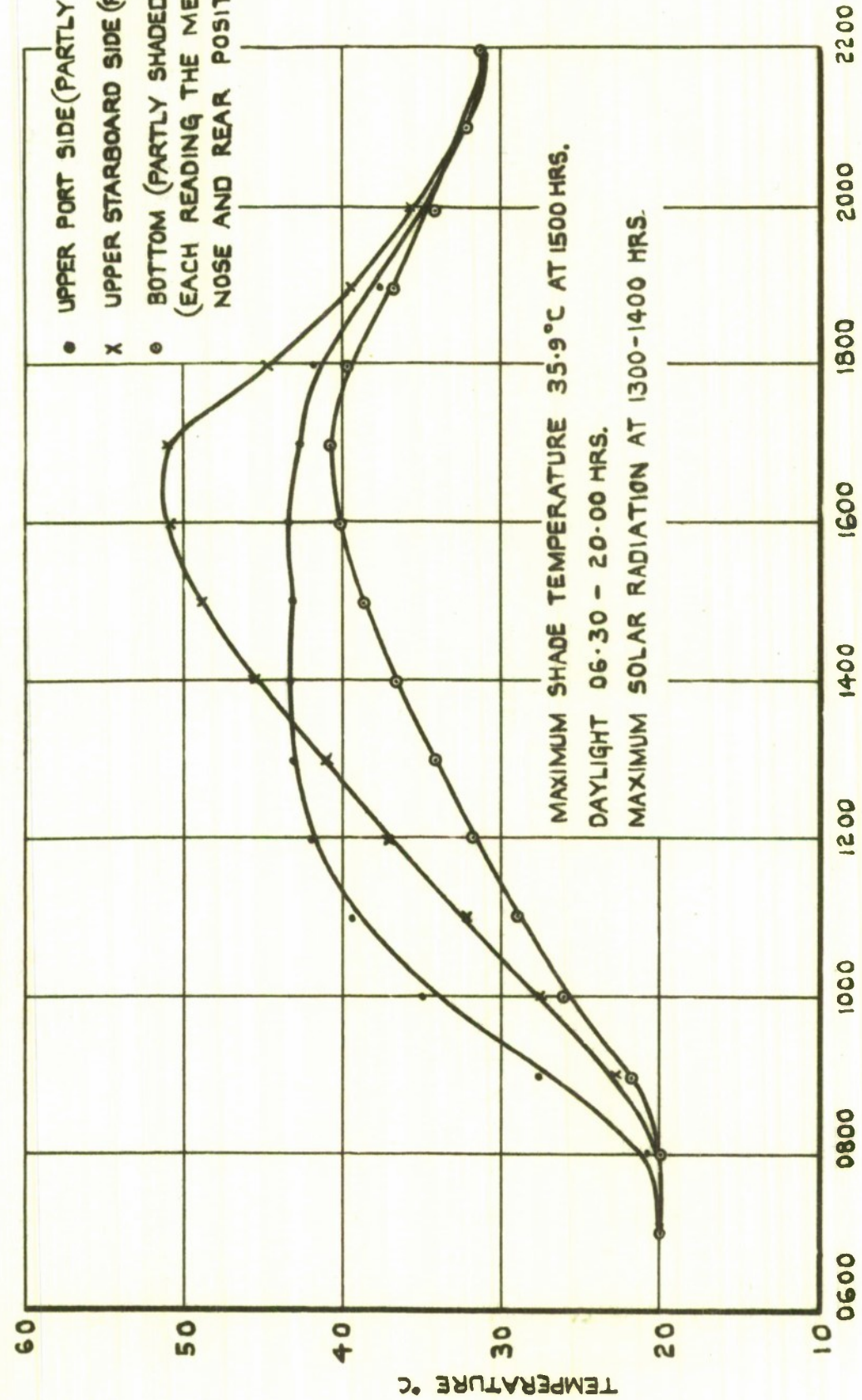


FIG. 3. 1000 LB. MK. 10 BOMB ON GROUND. TRIAL No. 1. TEMPERATURES RECORDED AT SURFACE OF BOMB FILLING. BOMB NOSE TO SOUTH.

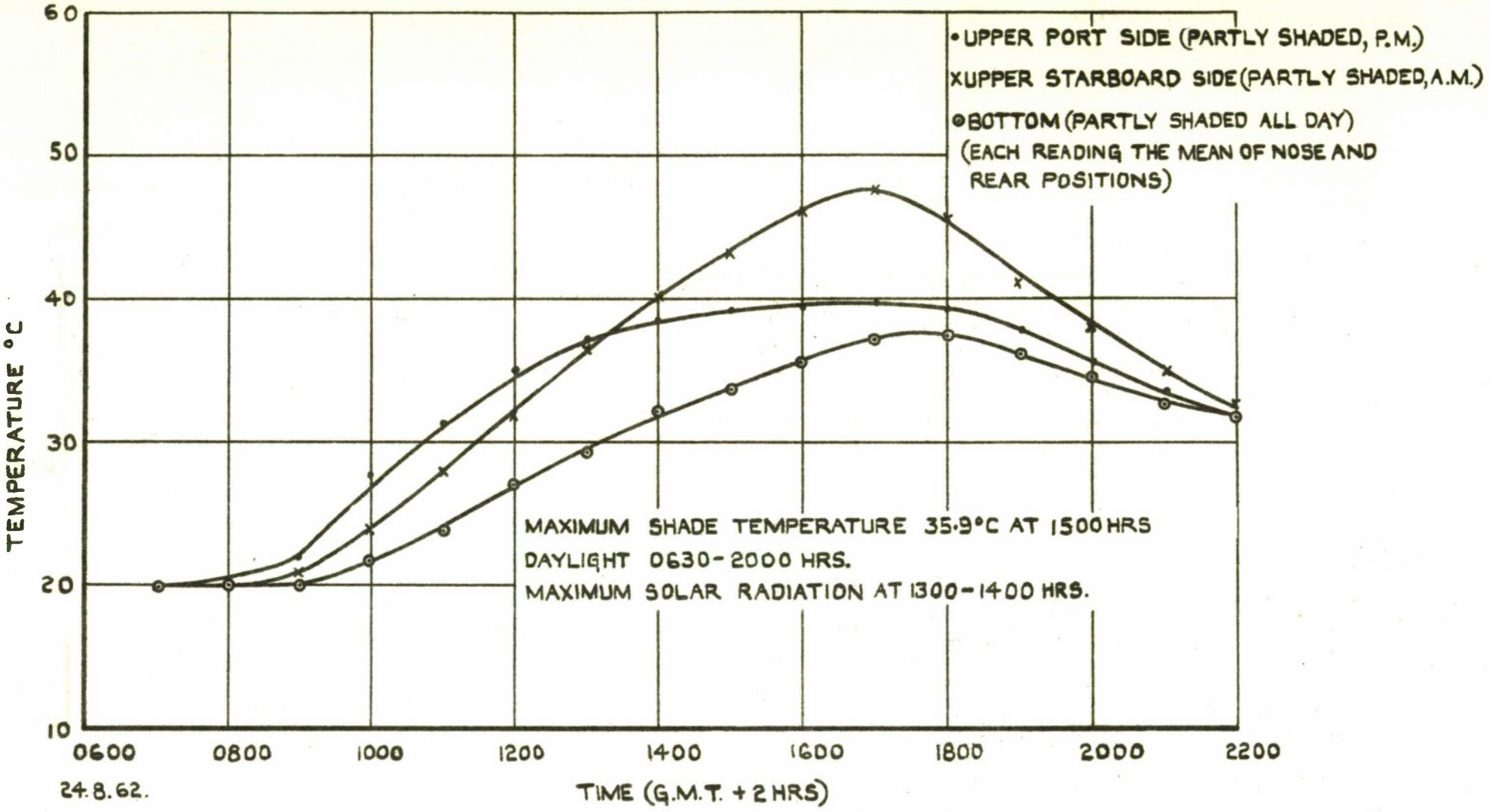


FIG. 4. 1000 LB. MK. 10 BOMB ON GROUND. TRIAL No. 1. TEMPERATURES RECORDED AT A DEPTH OF 3 CMS. INTO THE FILLING. BOMB NOSE TO SOUTH.

T.N. W.E. 13
FIG. 4.

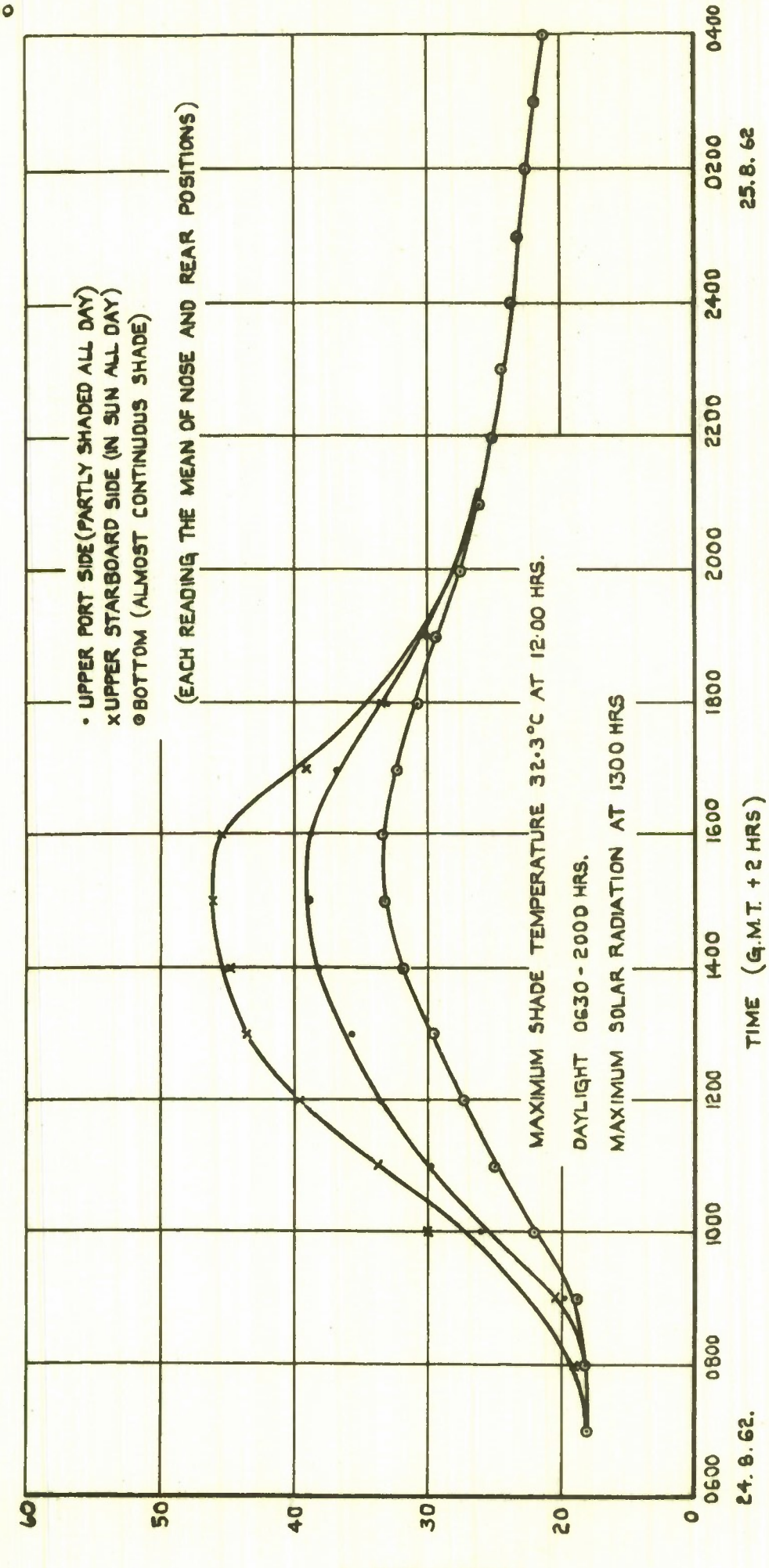


FIG.5. 1000 LB. MK.10 BOMB ON GROUND. TRIAL No.2 TEMPERATURES RECORDED ON BOMB SKIN. BOMB NOSE TO EAST.

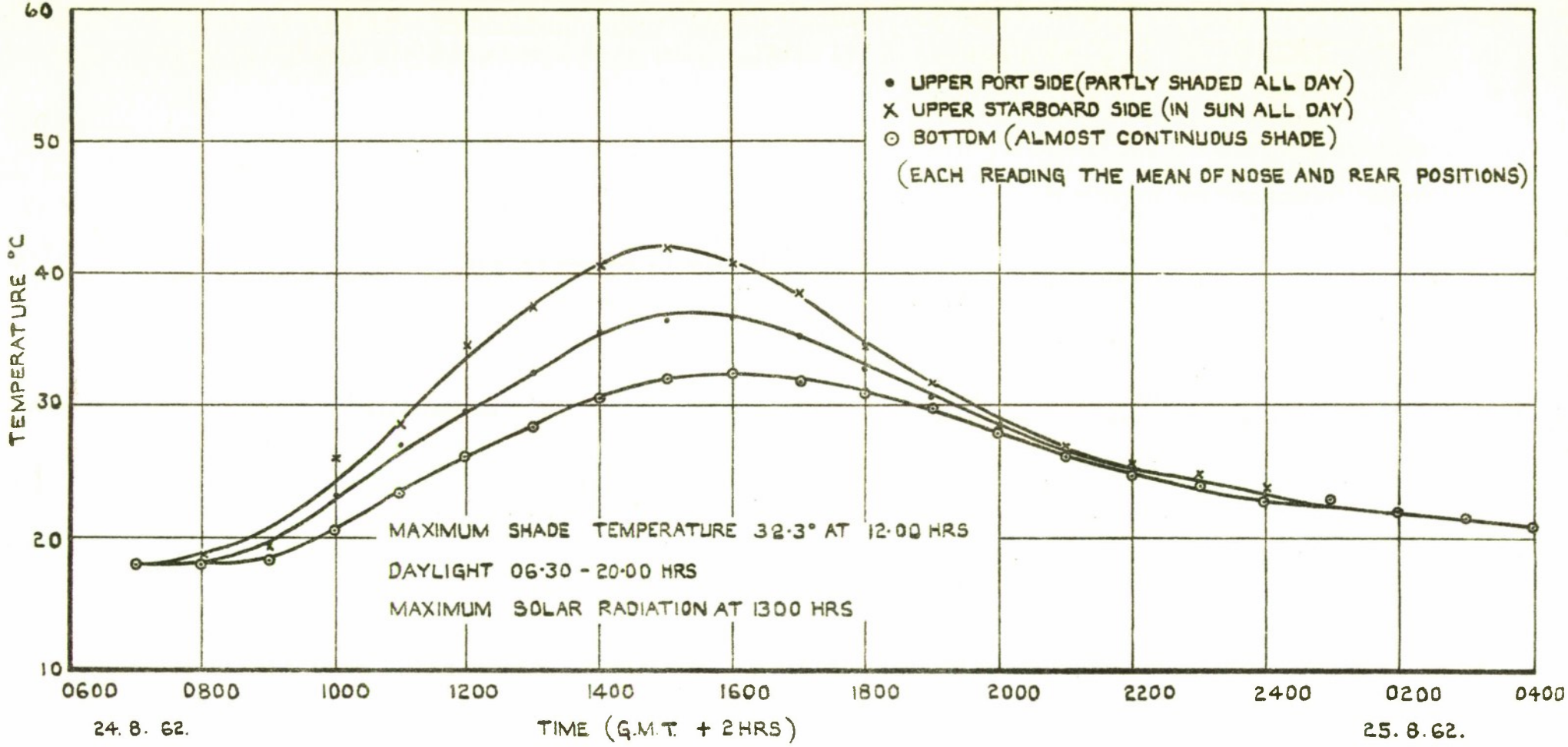


FIG.6. 1000 LB. MK.10 BOMB ON GROUND. TRIAL No.2. TEMPERATURES RECORDED AT SURFACE OF FILLING. BOMB NOSE TO EAST.

T.N.W.E.13
FIG. 6.

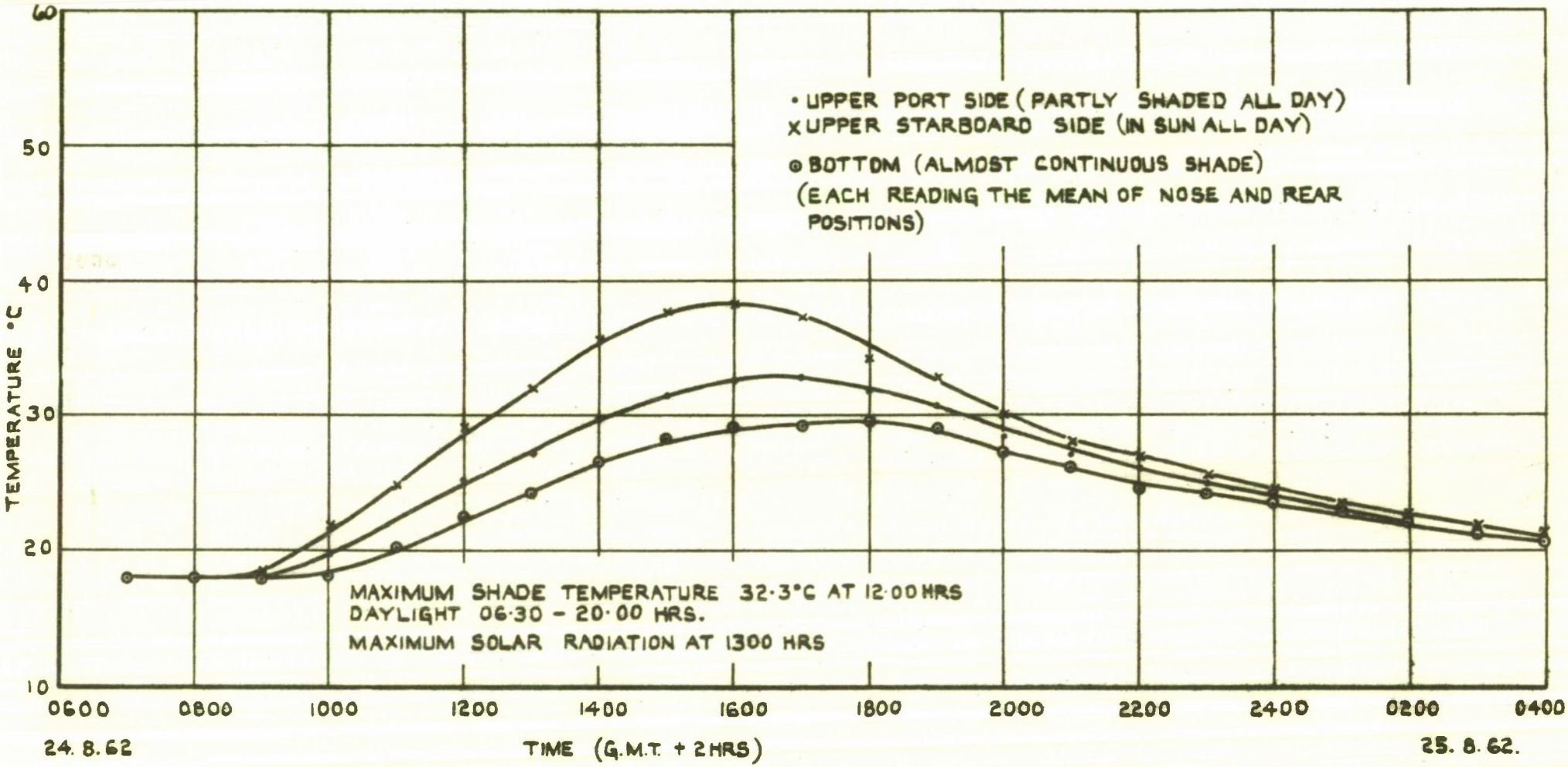


FIG. 7. 1000 LB. MK.10 BOMB ON GROUND. TRIAL No.2. TEMPERATURES RECORDED AT A DEPTH OF 3 CMS. INTO THE FILLING. BOMB NOSE TO EAST.

T.N.WE.13
FIG.7.

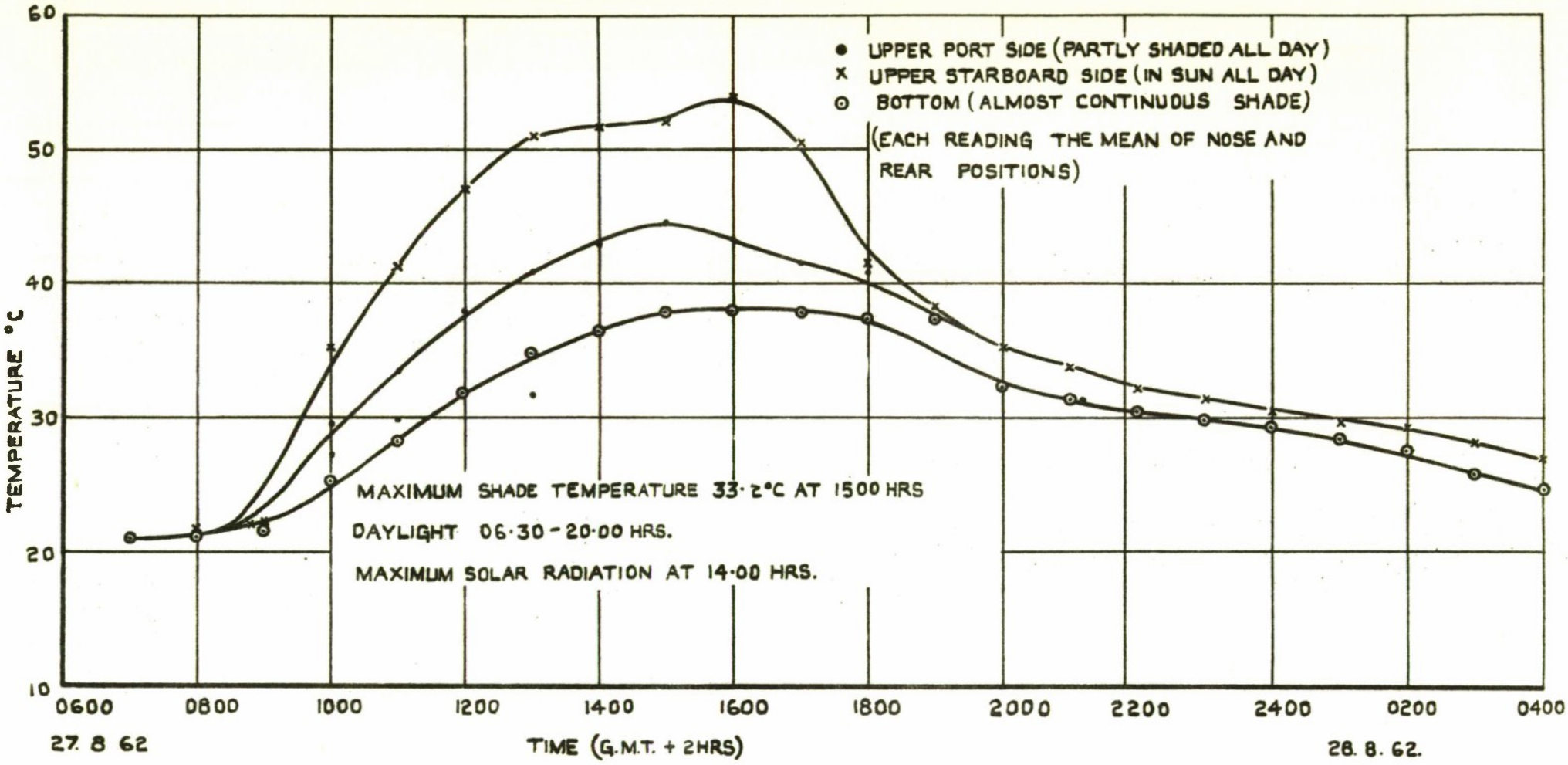


FIG.8. 1000 LB. MK.10 BOMB ON GROUND. TRIAL No.3. TEMPERATURES RECORDED ON BOMB SKIN. BOMB NOSE TO EAST.

T.N. W.E.13
FIG. 8.

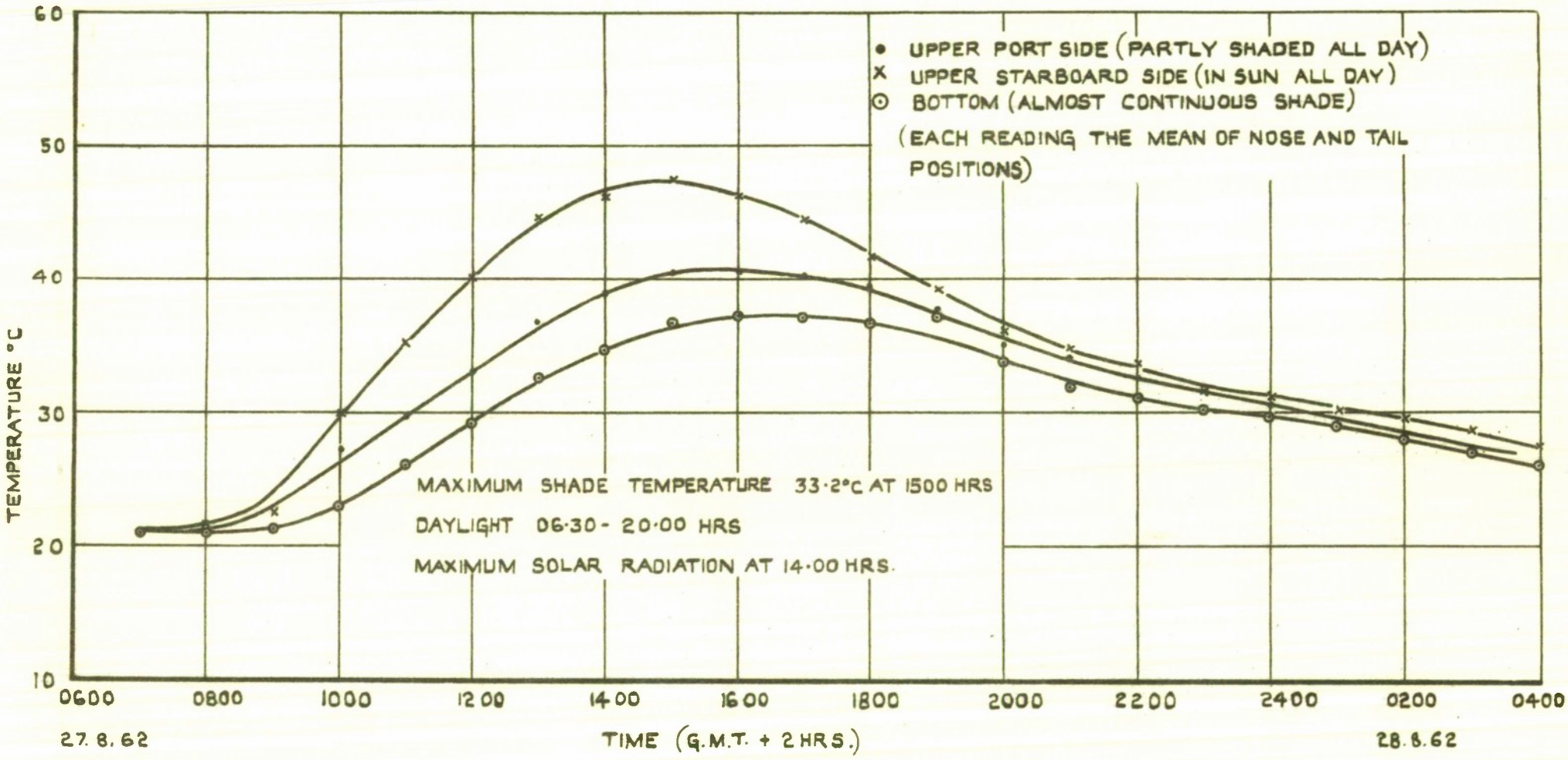


FIG.9. 1000 LB. MK.10 BOMB ON GROUND. TRIAL No.3. TEMPERATURES RECORDED AT SURFACE OF FILLING. BOMB NOSE TO EAST.

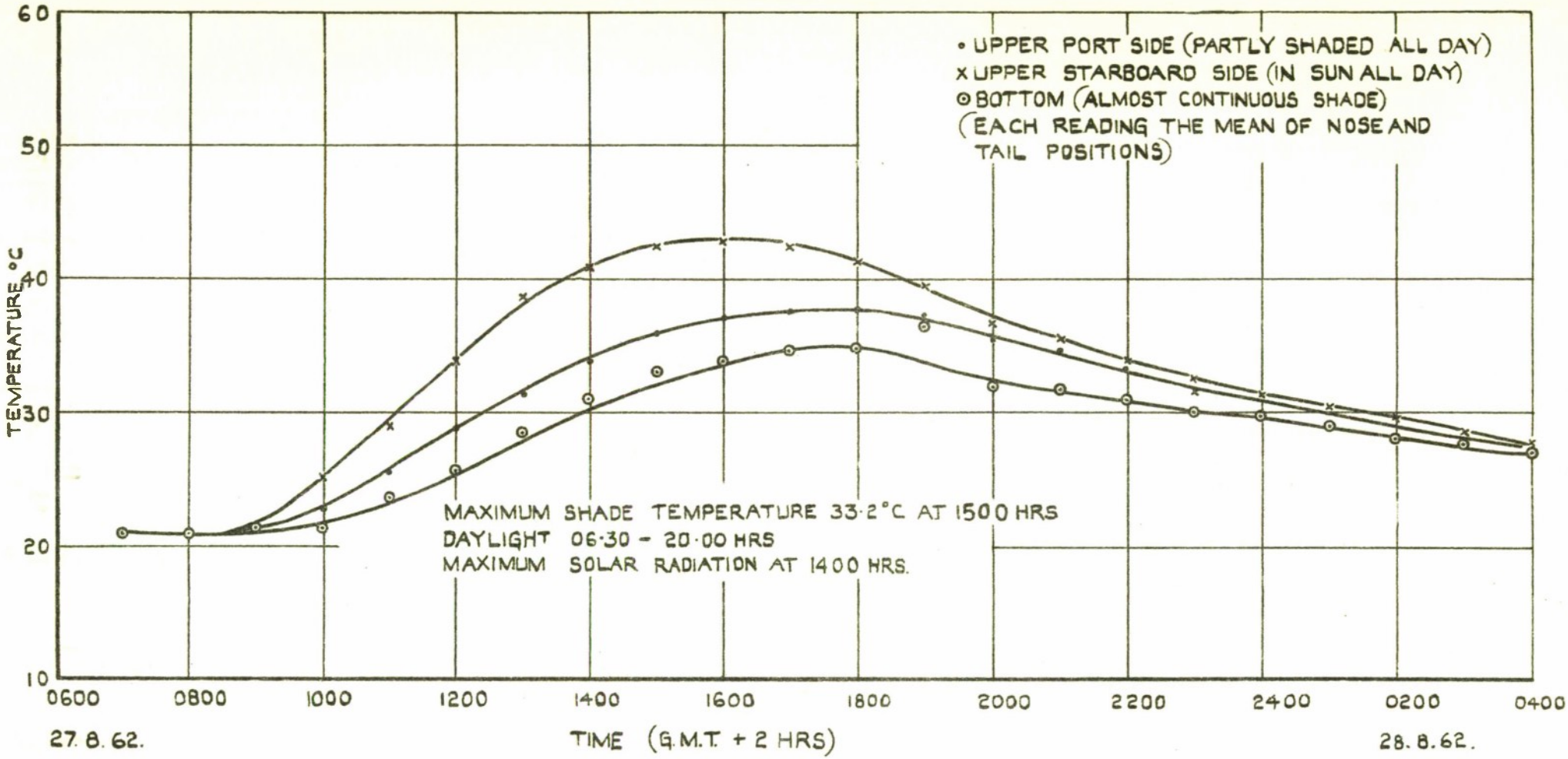
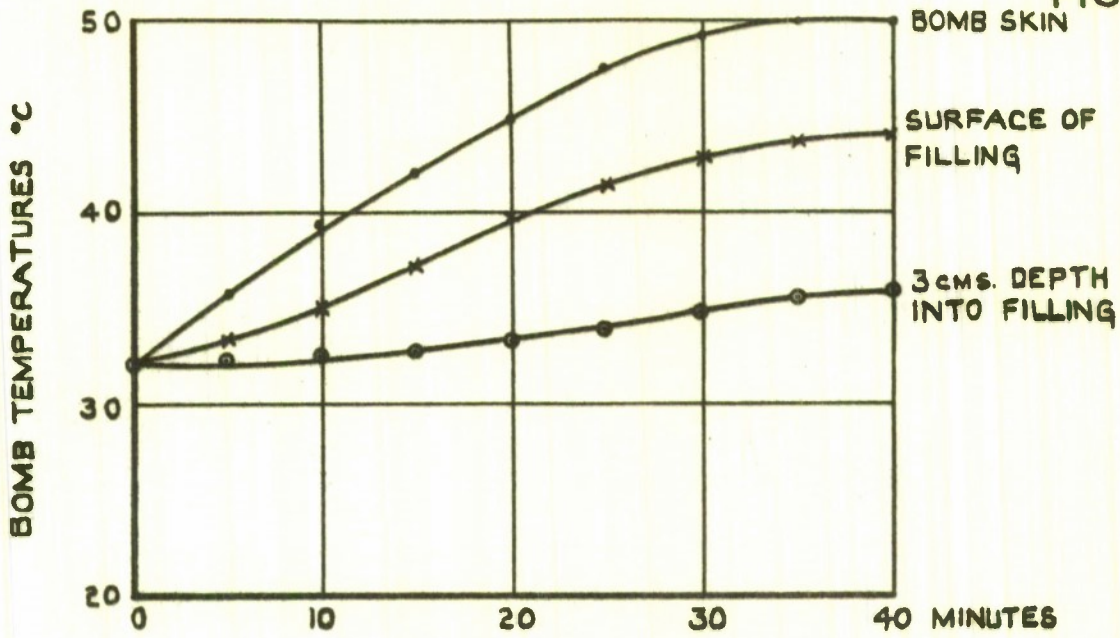
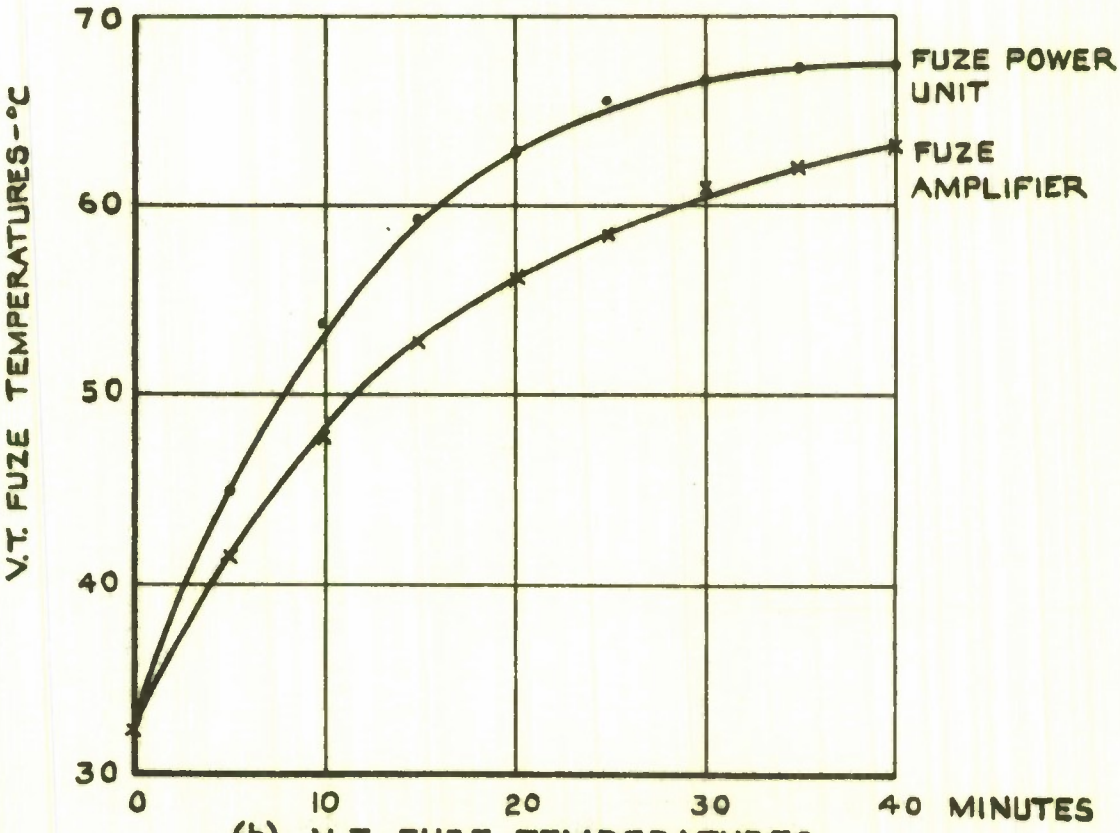


FIG.10. 1000 LB. MK.10 BOMB ON GROUND. TRIAL No.3. TEMPERATURES RECORDED AT A DEPTH OF 3 CMS. INTO THE FILLING. BOMB NOSE TO EAST.

T.N. WE. 13
FIG. 10.



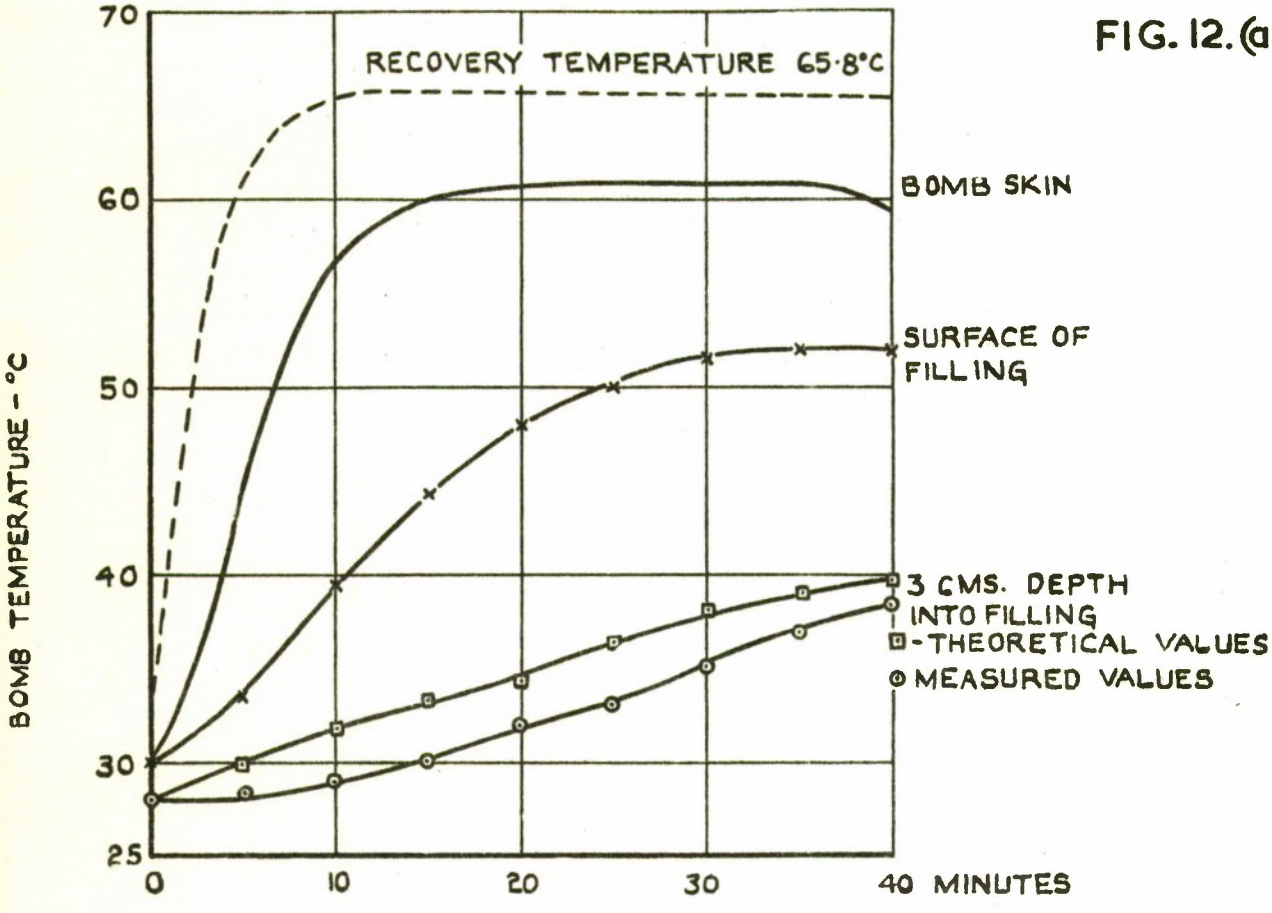
(a) BOMB TEMPERATURES.



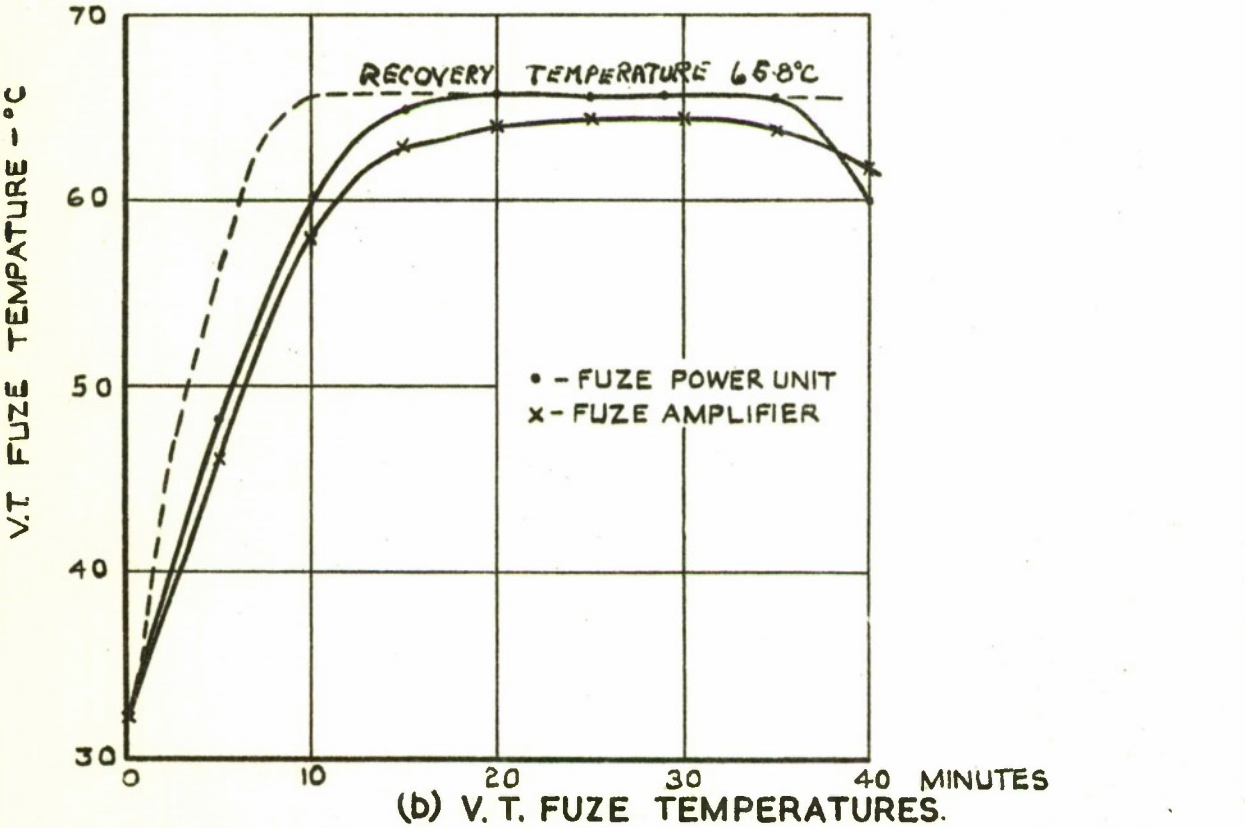
(b) V.T. FUZE TEMPERATURES

FIG. 11.(a&b) 1000 LB. MK. 10 BOMB IN BUCCANEER BOMB BAY. TEMPERATURES RECORDED IN BOMB AND V.T. FUZE DURING FLIGHT. TRIAL No.5.

FIG. 12. (a & b)



(a) BOMB TEMPERATURES



(b) V. T. FUZE TEMPERATURES.

FIG 12(a&b) 1000 LB. MK. 10 BOMB ON BUCCANEER PORT INBOARD PYLON. TEMPERATURES RECORDED IN BOMB AND V.T. FUZE DURING FLIGHT. TRIAL No. 6.

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