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# EVAPORATION MEASUREMENTS FROM BRITISH STANDARD (MET. OFFICE) TANKS AT KEW OBSERVATORY - EFFECT OF COVERING TANKS WITH NETTING

by B G Wales-Smith

1. INTRODUCTION. During the summer of 1969, it was found necessary to prevent ducks from settling on the water in the tanks, this was achieved by the use of netting. The specifications of the net used being as follows:

> $\frac{3}{4}$ inch square-mesh, commercial fruit net made of dark green plastic strands 12 thousandths of an inch in diameter.

2. EFFECTIVE AREA OF THE NETTING

With $\frac{3}{4}$" mesh over an area 72" x 72", assuming no sag, there would be 95 strands of netting running in each direction, each 72" in length and 12/1000" in width thus:

$$\text{area} = 2 \times 95 \times 72 \times \frac{12}{1000} = 164.16 \text{ sq in}$$

$$\text{total area of tank} = 72 \times 72 = 5184 \text{ sq in}$$

thus the net material amounted to 3.16% of the water surface area.

3. SITES AND NETTING ARRANGEMENTS

The two tanks concerned are at sites known as "old" and "new" and the measurements made from the tanks are so indexed in this brief examination.

In May and June 1969 both tanks were covered with identical nets. The net was removed from the new site tank during July and from the old site tank during August.

4. ARRANGEMENT AND EXAMINATION OF DATA

The 24-hour evaporation measurements are set out in Table I together with monthly totals. The totals for July ignore the 1st of the month when the new site tank was cleaned and no measurement was obtained.

The daily measurements are plotted in Figs 1 to 4. Casual inspection of the graphs reveals six occasions of very significant difference, namely

| | | | |
|---|---|---|---|
| May 1st | difference | 1.1 mm | (both tanks netted) |
| " 4th | " | 1.6 mm | " " " |
| Jul 29th | " | 5.3* mm | (old site tank netted) |
| " 30th | " | 1.4 mm | " " " " |
| Aug 2nd | " | 2.5† mm | (new site tank netted) |
| " 8th | " | 1.9† mm | " " " " |

and also a negative measurement of 0.3 mm on 28th July.

* large difference due to 9.2 mm loss from "open" tank could have been caused by ducks splashing.

† On Aug 2nd and 8th the greater losses were from the netted tank.

Summaries of observations at Kew on the 7 days concerned (0900 Z to 0900 Z following day) are as follows:

| Date | Rain (mm) | GMT 1000-0900 Wind Speed (kts) | Max Temp °C | Sun (hrs) | 1000-0900 GMT (24 hrs) No. of hrs with R.H* ⩾ 90% | ⩽ 50% |
|---|---|---|---|---|---|---|
| May 1st | Tr | 0-13 K | 14.2 | 10.3 | 9 | 4 |
| " 4th | 0 | 2- 9 K | 16.8 | 6.0 | 1 | 0 |
| Jul 28th | 5.4 | 0- 9 K | 24.3 | 0 | 6 | 1 |
| " 29th | 31.5 | 1-10 K | 18.7 | 0 | 12 | 0 |
| " 30th | 0 | 0- 6 K | 22.6 | 11.7 | 7 | 7 |
| Aug 2nd | 57.3 | 1-12 K | 24.6 | 2.9 | 17 | 0 |
| " 8th | Tr | 1-10 K | 27.7 | 11.0 | 3 | 7 |

Both tanks were netted in May and there were no noteworthy weather features to explain the differences in the measurements.

The 28 July, when a negative measurement was obtained from the new site tank, was a very warm but dull day with light winds and the rain (measured to the 28th) fell between 0500 and 0900 on the 29th.

The 29 July was a wet day. (see footnote * on previous page).

The 30 July was not exceptional in any sense.

The 2 August had heavy rain and thunderstorms during the evening and night.

The 8 August was a very ordinary summer day in all respects.

Since there were large falls of rain on each of the two days when very large differences in evaporation measurements occurred and since on 29 July the netted tank lost less water than the other but on the 2 August the netted tank lost more water than the other no conclusions can be drawn about the effects of netting.

With the exception of the days already examined, the agreement between the tanks was no worse when only one was netted than when both were netted.

Differences between daily measurements are set out in Table II. It can be seen from the + and - totals (bearing in mind the very high new site value on July 29th) that there are certainly no significant systematic effects involved. This view is further supported by the distributions of + and - differences in each month.

Numbersof cases of differences of various magnitudes (mm) in each month are given in Table III. There were 61 days of measurements when both tanks were netted and 61 days when only one tank was netted at a time.

As can be seen, there is very little difference between the distributions.

*RH = relative humidity

5. ANALYSIS BY REGRESSION AND CORRELATION.

Fig. 5 June-July-August 1968 compares measurements from the two British Standard tanks at Kew without netting ("open"), the correlation coefficient R being .867. If we take only the month of August 1968 the value of R increases to .944.

Fig. 6 May-June 1969 compares the tanks both netted ("covered") and here R is .934.

Fig.7. July 1969 compares the tanks when one is covered by netting and gives R as .813 but on 29th. July the readings were "New" 9.2 mm and "Old" 3.9 mm. If we reject this pair as misleading and assume that the 9.2 mm loss may have been due to splashing by ducks or to some other cause (the 9.2 mm loss occurred from the "open" tank) we obtain R = .951

Fig.8. August 1969 compares the tanks when the netting has been transferred from the "Old" to the "New" tank and gives R = .904

The highest R occurred with one tank covered and the lowest R occurred also with one covered (if we include the pair of measurements for 29th. July) but for the 3-month period with both "open" if we exclude 29th. July.

The regression equations are given on Figures 5 to 8.

All the intercepts are less than 0.3 mm and the slopes of regression lines are between 42 and 48 degrees.

Slopes greater than 45 degrees occur with : both tanks open
: one tank open

Slopes less than 45 degrees occur with : both tanks open
: both tanks covered

This analysis gives considerable support to the evidence presented in Table 3 and to the conclusion that the effects of netting were negligible.

## 6. CONCLUSIONS

We must conclude, therefore that there is no evidence that the netting used at Kew had any systematic and significant effect on the evaporation measurements made there during the period May-August 1969.

If any ducks did, in fact, settle on either tank when not netted they do not appear to have interfered with the measurements of evaporation.

It is hoped to carry out a similar examination of results obtained during the summer of 1970.

It would seem that the type of netting used had no obvious effect under the following, possible headings:

a. Absorption of incoming radiation - tending to reduce evaporation.

b. Reflection of incoming radiation - tending to reduce evaporation.

c. Reflection of outgoing radiation - tending to increase evaporation.

d. Interception and evaporation of rainfall and dew - resulting in an over-estimate of evaporation (the water loss read from the netted tank would be greater than that from the open tank by the amount of rain lost from the net but the full rainfall, by rain-gauge, would still be added to the water loss value).

e. Modification of air flow over the water surface - result would have to be determined by experiment.

In view of the evidence of Table III no examination of water temperatures is presented.

The distribution of values of daily $\delta = E_{new} - E_{old}$ when both tanks were netted in May and June 1969 and when alternate tanks were netted for a month each in July and August 1969 remained almost exactly the same.

It may be argued that there is still an important unknown, whether the ducks splashed water out of both tanks, equally, when both were open and out of whichever tank was open during July and August. For this to have happened but for the effects to be concealed it would be necessary for the ducks to splash x mm. of water from the open tank in a given period whilst the netting had the effect of increasing the value of open water evaporation by x mm. The lettered conclusions (above) and the general view of those who have netted tanks against

interference by birds and animals is that netting tends to decrease the water loss by evaporation. The suggestion of the present investigation is that the type of netting used, when applied to sunken, British Standard tanks at Kew Observatory did not significantly influence the water loss by evaporation.

ACKNOWLEDGEMENT

This investigation was carried out at the suggestion of Mr S G Crawford (Superintendent of Kew Observatory); his co-operation and that of his staff is acknowledged with thanks.

NOTE: This memo is circulated for the purpose of discussion. Comments and suggestions will be welcomed by the author.

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# TABLE I

EVAPORATION MEASUREMENTS 09-09Z MADE WITH BRITISH STANDARD (M.O.) TANKS AT KEW OBSERVATORY (* = TANK COVERED BY NETTING) (New/old headings refer to sites) VALUES IN MM.

| DATE | MAY 1969 | | JUNE 1969 | | JULY 1969 | | AUGUST 1969 | |
|---|---|---|---|---|---|---|---|---|
| | New* | Old* | New* | Old* | New | Old* | New* | Old |
| 1 | 3·2 | 2·1 | 2·4 | 2·4 | * — | 2·6 | 0·8 | 0·7 |
| 2 | 1·2 | 1·1 | 3·2 | 3·0 | 2·9 | 3·1 | 8·8 | 6·3 |
| 3 | 1·4 | 1·7 | 3·3 | 2·8 | 2·9 | 3·1 | 3·1 | 2·4 |
| 4 | 3·3 | 1·7 | 3·5 | 3·9 | 5·7 | 5·2 | 1·9 | 2·7 |
| 5 | 2·5 | 2·1 | 1·9 | 2·5 | 5·0 | 4·5 | 2·2 | 2·6 |
| 6 | 1·3 | 1·6 | 3·3 | 2·5 | 3·6 | 3·0 | 2·3 | 2·5 |
| 7 | 1·9 | 2·0 | 3·6 | 3·9 | 3·0 | 2·4 | 3·6 | 4·3 |
| 8 | 1·4 | 2·4 | 4·4 | 5·0 | 2·5 | 2·6 | 3·7 | 1·8 |
| 9 | 1·9 | 1·2 | 5·9 | 6·2 | 1·9 | 1·3 | 1·3 | 1·3 |
| 10 | 0·2 | 0·6 | 4·3 | 4·2 | 0·4 | 0·7 | 2·4 | 2·6 |
| 11 | 1·4 | 1·5 | 5·7 | 5·8 | 3·0 | 3·1 | 2·3 | 2·5 |
| 12 | 0·7 | 0·6 | 4·8 | 5·1 | 2·7 | 2·8 | 4·2 | 4·9 |
| 13 | 3·2 | 2·8 | 3·8 | 3·9 | 3·3 | 3·5 | 1·4 | 1·2 |
| 14 | 1·5 | 1·4 | 4·7 | 4·4 | 4·2 | 4·6 | 1·6 | 1·4 |
| 15 | 1·9 | 2·1 | 2·8 | 3·2 | 4·0 | 4·2 | 1·3 | 1·7 |
| 16 | 2·5 | 2·2 | 3·2 | 3·2 | 6·4 | 6·3 | 3·1 | 3·0 |
| 17 | 1·9 | 1·3 | 1·5 | 1·2 | 6·5 | 6·1 | 1·8 | 2·0 |
| 18 | 1·9 | 1·7 | 2·8 | 3·2 | 4·7 | 4·7 | 1·4 | 1·3 |
| 19 | 1·3 | 1·5 | 2·8 | 3·0 | 3·7 | 3·2 | 3·0 | 3·0 |
| 20 | 1·5 | 1·4 | 2·7 | 2·5 | 2·6 | 2·3 | 3·8 | 3·5 |
| 21 | 1·2 | 1·3 | 2·3 | 2·6 | 3·0 | 2·6 | 2·3 | 2·7 |
| 22 | 3·3 | 2·6 | 2·1 | 2·2 | 4·1 | 4·2 | 2·9 | 2·8 |
| 23 | 3·0 | 3·5 | 0·9 | 1·2 | 2·8 | 3·0 | 2·1 | 2·3 |
| 24 | 0·7 | 1·0 | 2·2 | 1·7 | 2·7 | 3·2 | 2·4 | 2·1 |
| 25 | 2·5 | 2·5 | 3·0 | 2·8 | 3·7 | 3·3 | 3·7 | 3·8 |
| 26 | 2·8 | 3·0 | 2·7 | 3·4 | 3·9 | 3·7 | 0·7 | 0·9 |
| 27 | 1·3 | 1·2 | 4·0 | 4·0 | 4·2 | 4·0 | 3·7 | 3·3 |
| 28 | 2·4 | 3·1 | 2·9 | 3·3 | −0·3 | 0·7 | 2·1 | 2·2 |
| 29 | 3·7 | 3·1 | 4·7 | 5·1 | 9·2 | 3·9 | 2·0 | 2·0 |
| 30 | 2·2 | 2·1 | 5·0 | 4·5 | 3·2 | 1·8 | 0·7 | 0·5 |
| 31 | 2·0 | 2·3 | X | X | 2·2 | 2·4 | 1·9 | 1·9 |
| TOTALS | 61·2 | 58·7 | 100·4 | 102·7 | 107·7 (30 days) | 99·5 (30 days) | 78·5 | 76·2 |

* TANK CLEANED.

## TABLE II

DIFFERENCE $\delta$ BETWEEN DAILY EVAPORATION MEASUREMENTS AT TWO TANKS. ($\delta = E_{new} - E_{old}$)
MAY – AUGUST 1969

| DATE | MAY New-Old | JUN New-Old | JUL New-Old | AUG New-Old |
|---|---|---|---|---|
| 1 | 1.1 | 0 | – | 0.1 |
| 2 | 0.1 | 0.2 | -0.2 | 2.5 |
| 3 | -0.3 | 0.5 | -0.2 | 0.7 |
| 4 | 1.6 | -0.4 | 0.5 | -0.8 |
| 5 | 0.4 | -0.6 | 0.5 | -0.4 |
| 6 | +0.3 | 0.8 | 0.6 | -0.2 |
| 7 | -0.1 | -0.3 | 0.6 | -0.7 |
| 8 | -1.0 | -0.6 | -0.1 | 1.9 |
| 9 | 0.7 | -0.3 | 0.6 | 0 |
| 10 | -0.4 | 0.1 | -0.3 | -0.2 |
| 11 | -0.1 | -0.1 | -0.1 | -0.2 |
| 12 | 0.1 | -0.3 | -0.1 | -0.7 |
| 13 | 0.4 | -0.1 | -0.2 | 0.2 |
| 14 | 0.1 | 0.3 | -0.4 | 0.2 |
| 15 | -0.2 | -0.4 | -0.2 | -0.4 |
| 16 | 0.3 | 0 | 0.1 | 0.1 |
| 17 | 0.6 | 0.3 | 0.4 | -0.2 |
| 18 | 0.2 | -0.4 | 0 | 0.1 |
| 19 | -0.2 | -0.2 | 0.5 | 0 |
| 20 | 0.1 | 0.2 | 0.3 | 0.3 |
| 21 | -0.1 | -0.3 | 0.4 | -0.4 |
| 22 | 0.7 | -0.1 | -0.1 | 0.1 |
| 23 | +0.5 | -0.3 | -0.2 | -0.2 |
| 24 | -0.3 | 0.5 | -0.5 | 0.3 |
| 25 | 0 | 0.2 | 0.4 | -0.1 |
| 26 | -0.2 | -0.7 | 0.2 | -0.2 |
| 27 | 0.1 | 0 | 0.2 | 0.4 |
| 28 | -0.7 | -0.4 | -1.0 | -0.1 |
| 29 | 0.6 | -0.4 | 5.3 | 0 |
| 30 | 0.1 | 0.5 | 1.4 | 0.2 |
| 31 | -0.3 | | -0.2 | 0 |
| TOTAL + | +7.2 | +3.6 | +12.0 | +7.1 |
| TOTAL – | -4.7 | -5.9 | -3.8 | -4.8 |
| SUM | +2.5 | -2.3 | +8.2 | +2.3 |
| MINUSES | 14 | 17 | 14 | 14 |
| PLUSES | 16 | 10 | 15 | 13 |
| ZERO | 1 | 3 | 1 | 4 |

## TABLE III

NUMBERS OF CASES OF DIFFERENCES BETWEEN DAILY EVAPORATION MEASUREMENTS (MM) IN RANGES AS GIVEN:

| | 0 | 0.1 – 0.3 | 0.4 – 0.7 | 0.8 – 1.0 | 1.1 – 1.5 | 1.6 – 2.0 | 2.1 – 3.0 | 3.1 – 4.0 | 4.1 – 5.0 | 5.1 – 6.0 | DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MAY | 1 | 18 | 9 | 1 | 1 | 1 | | | | | 31 |
| JUN | 3 | 15 | 11 | 1 | | | | | | | 30 |
| MAY + JUNE | 4 | 33 | 20 | 2 | 1 | 1 | | | | | 61 |
| JUL | 1 | 15 | 11 | 1 | 1 | | | | | 1 | 30 |
| AUG | 4 | 17 | 7 | 1 | | 1 | 1 | | | | 31 |
| JUL + AUG | 5 | 32 | 18 | 2 | 1 | 1 | 1 | | | 1 | 61 |

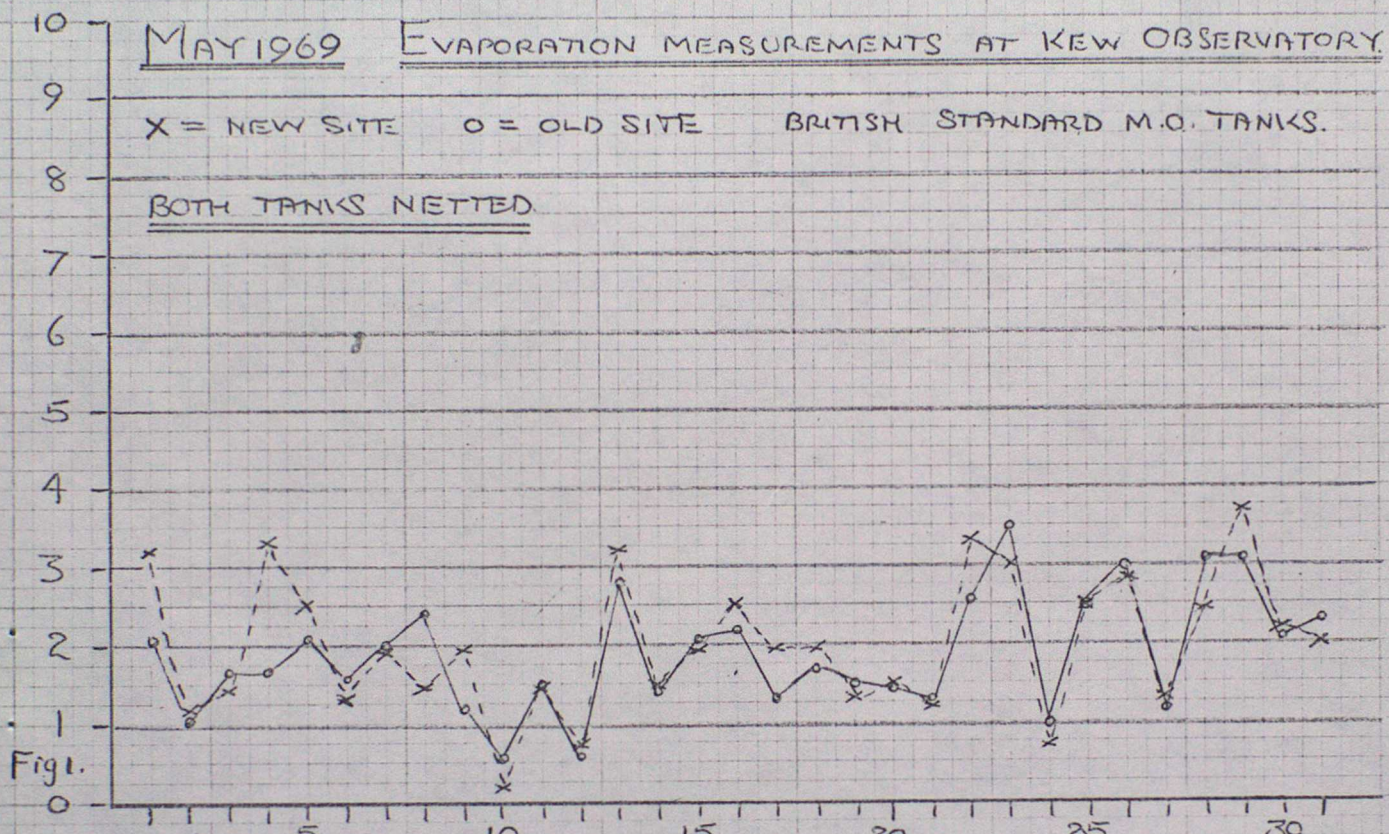

MAY 1969 EVAPORATION MEASUREMENTS AT KEW OBSERVATORY
X = NEW SITE O = OLD SITE BRITISH STANDARD M.O. TANKS.
BOTH TANKS NETTED
10
9
8
7
6
5
4
3
2
1
0
5
10
15
20
25
30

Fig1.

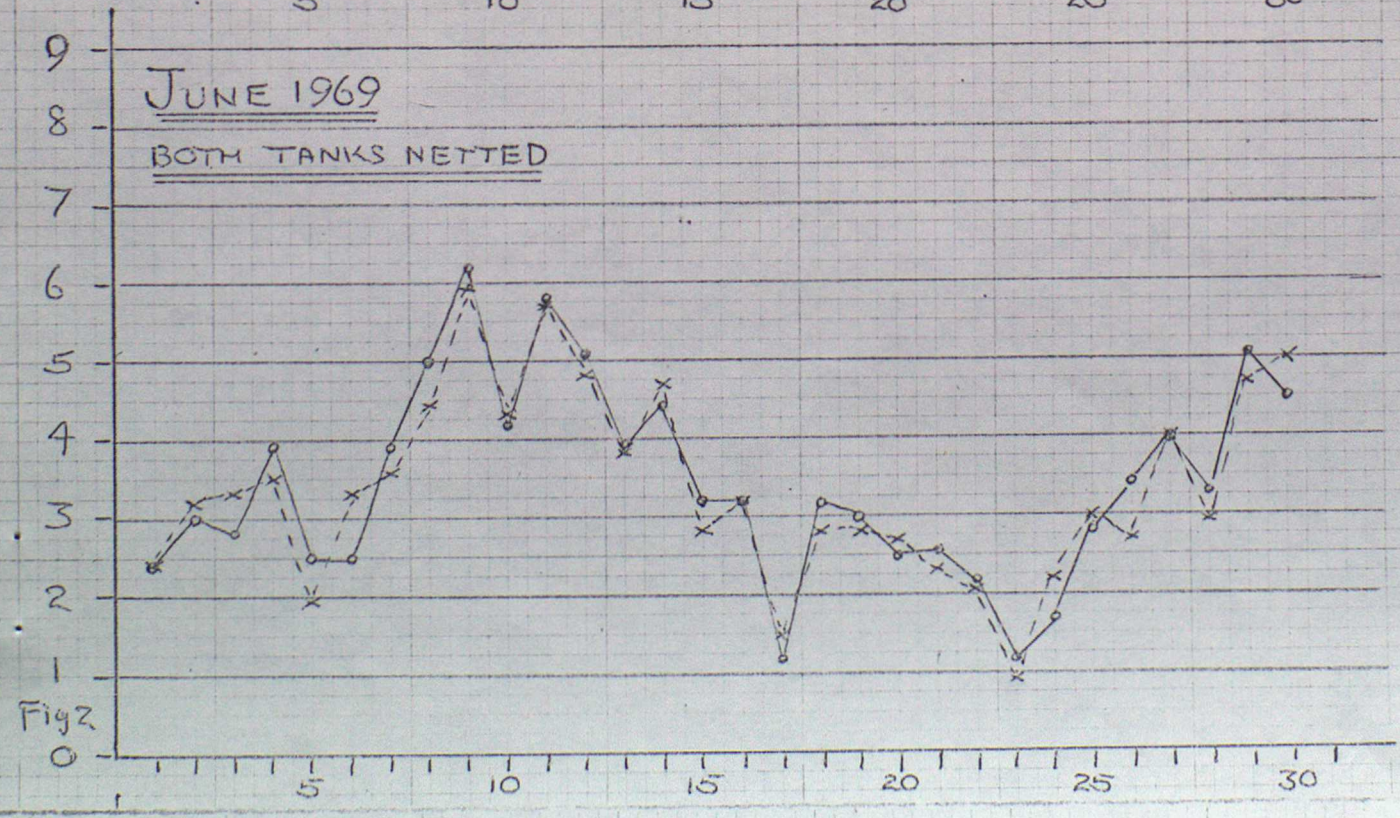

JUNE 1969
BOTH TANKS NETTED
9
8
7
6
5
4
3
2
1
0
5
10
15
20
25
30

Fig2.

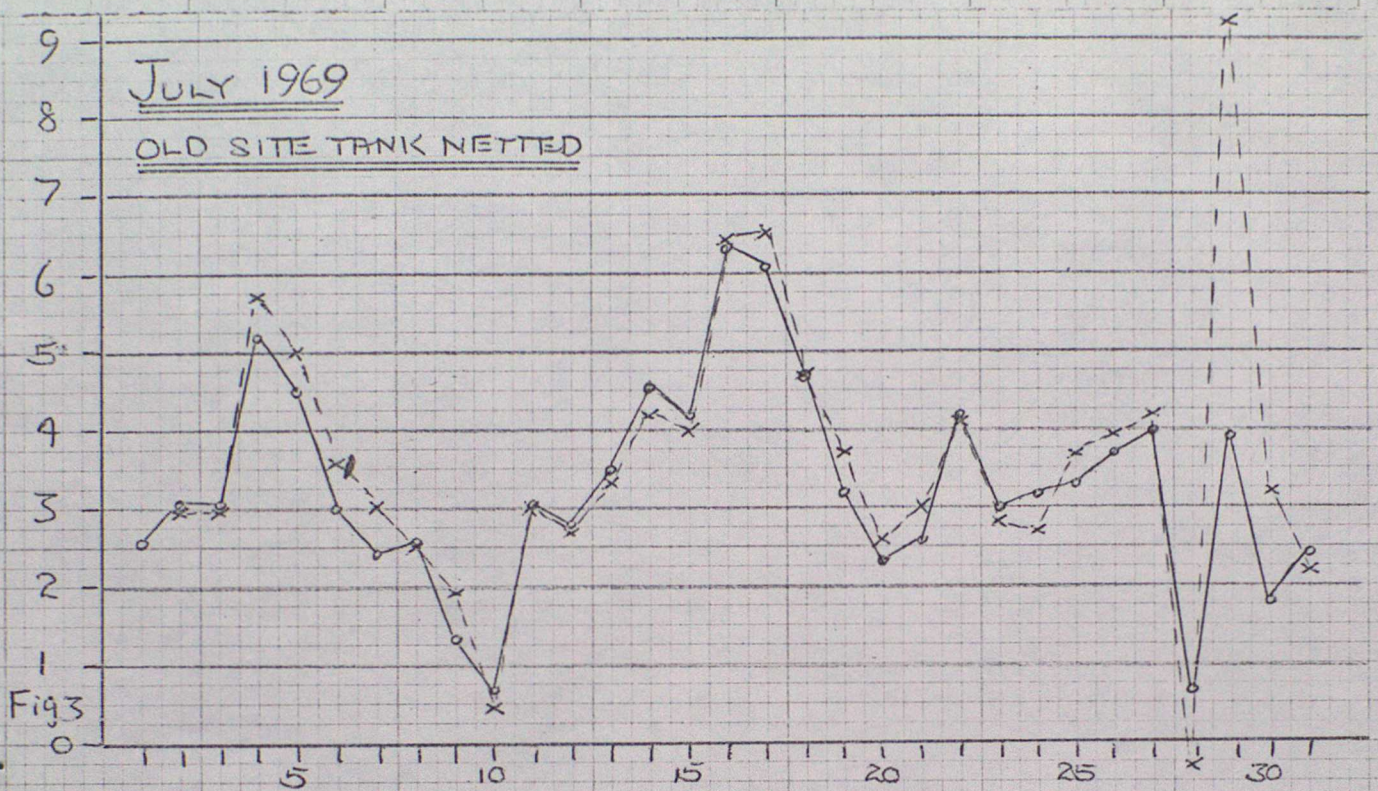

JULY 1969
OLD SITE TANK NETTED
9
8
7
6
5
4
3
2
1
0
5
10
15
20
25
30

Fig3

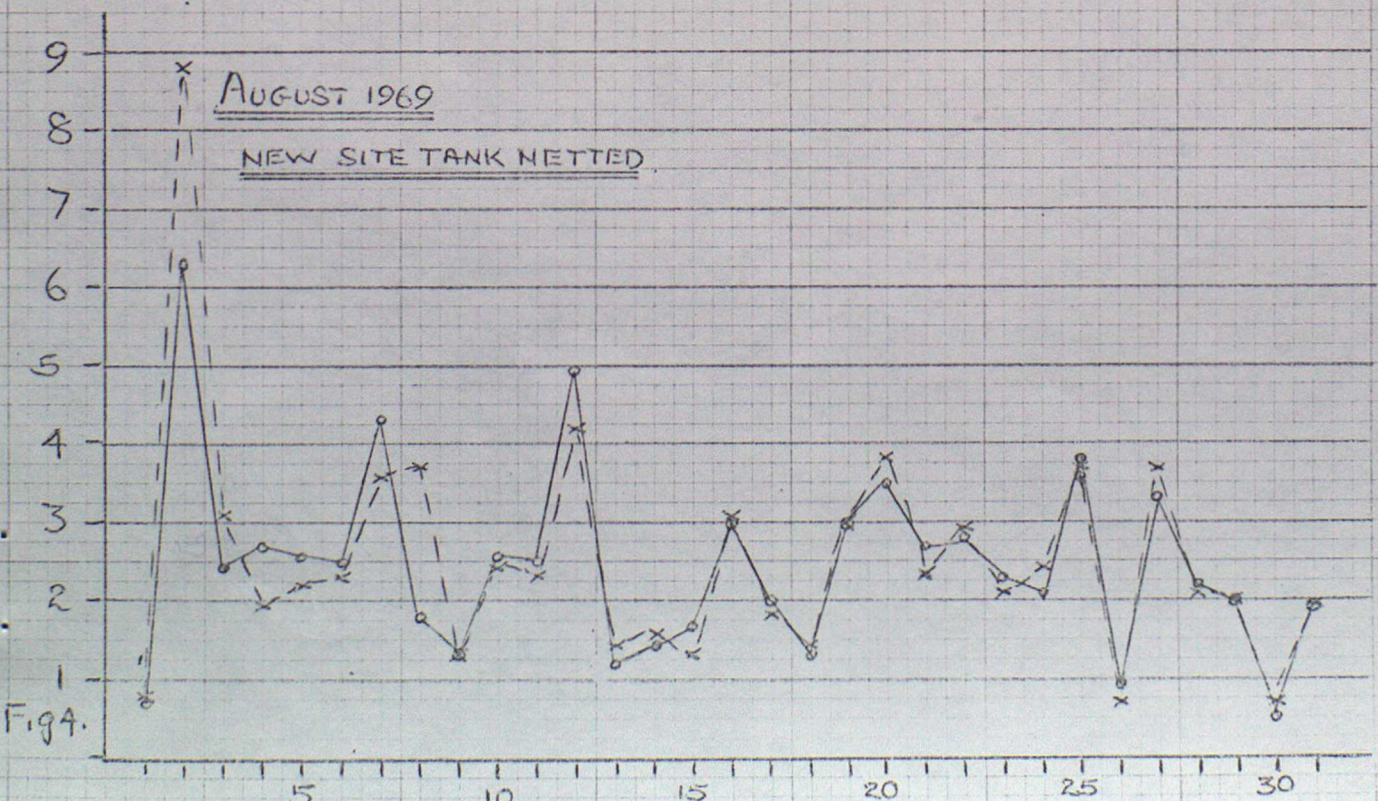

AUGUST 1969
NEW SITE TANK NETTED
9
8
7
6
5
4
3
2
1
5
10
15
20
25
30

Fig4.

Fig. 5.

KEW OBSERVATORY.
JUNE – AUGUST 1968.

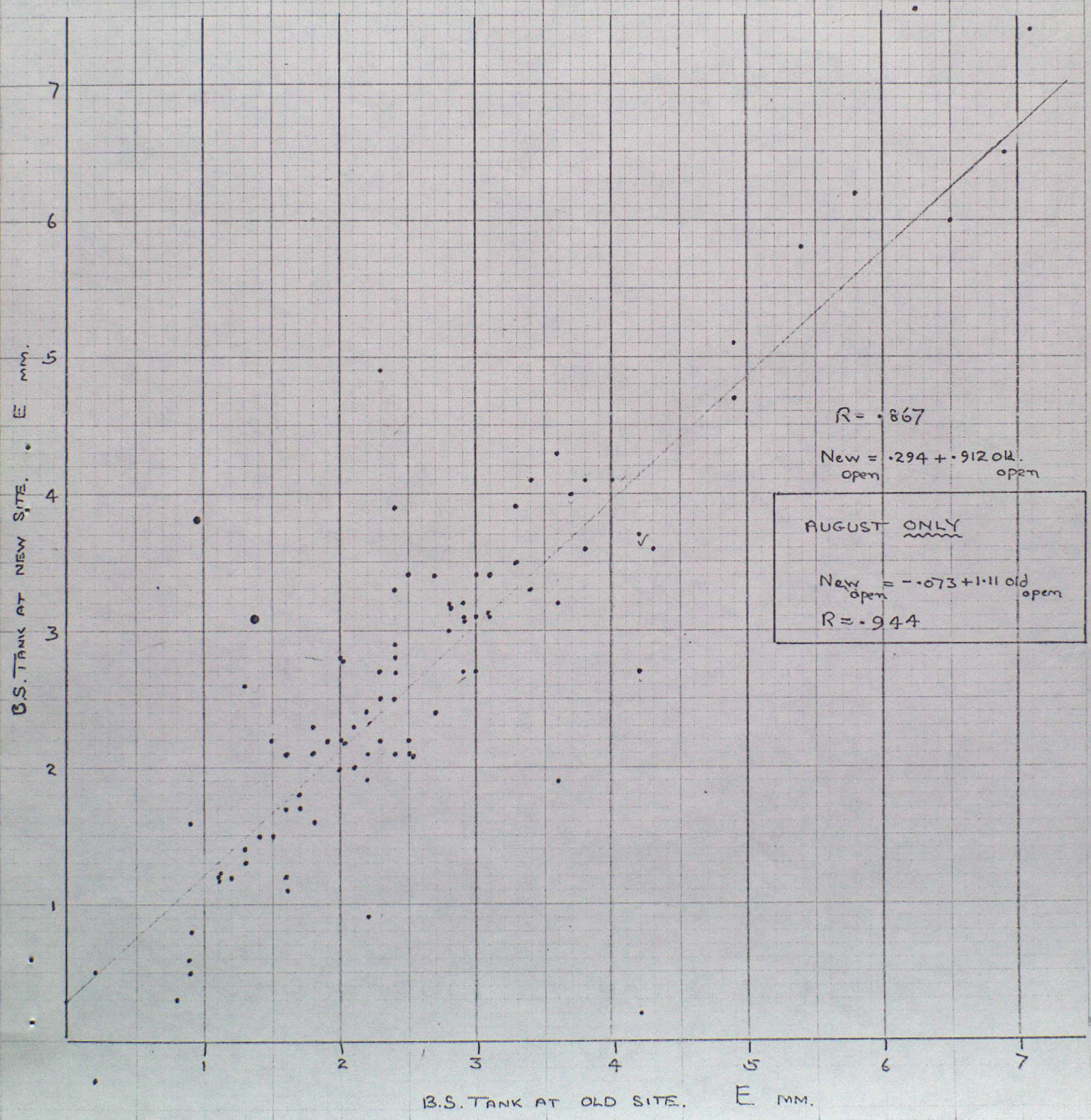


Fig. 6

MAY AND JUNE 1969

KEW.

• = DAILY VALUES

X = PENTAD MEAN VALUES

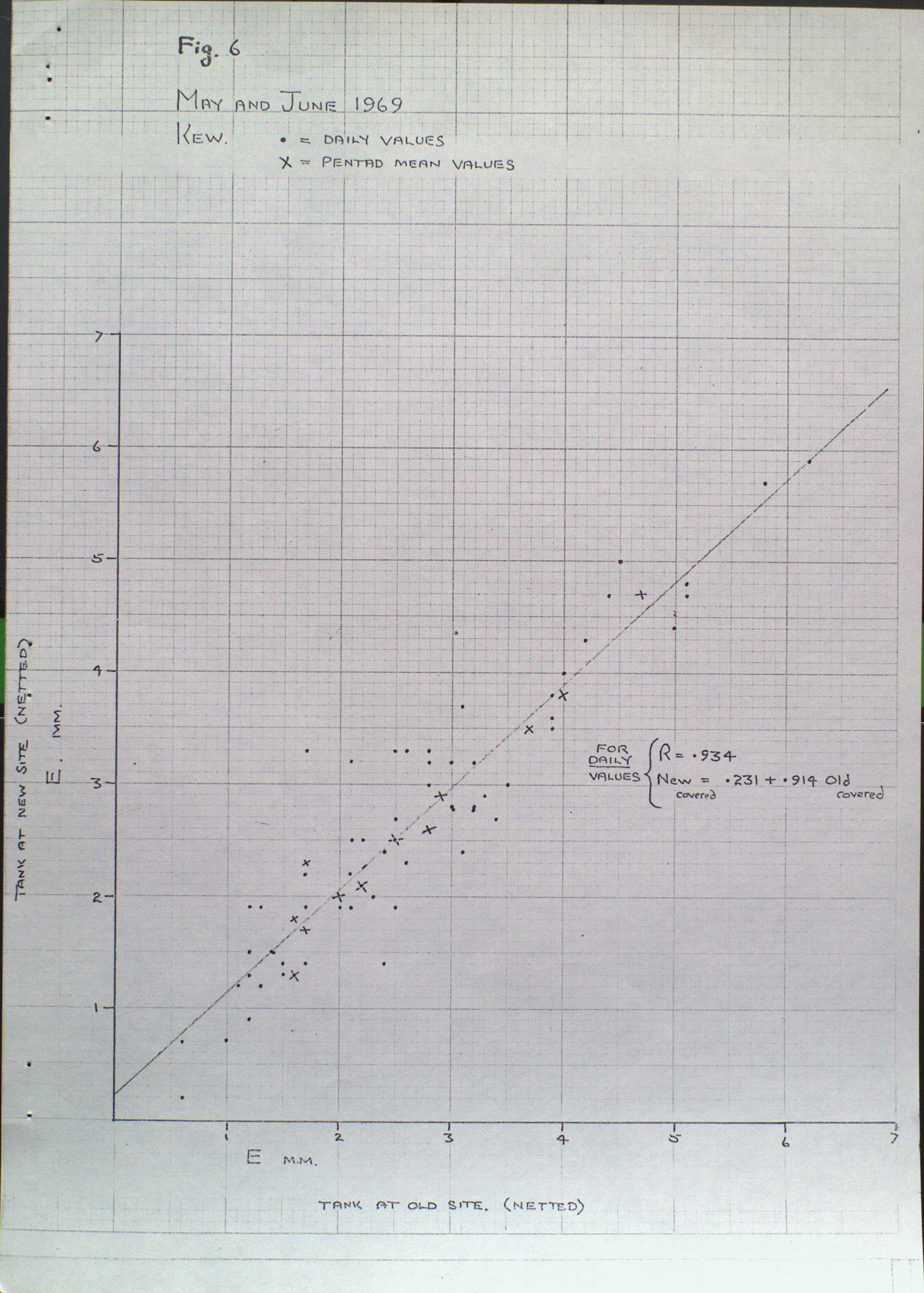


Fig. 7

JULY 1969

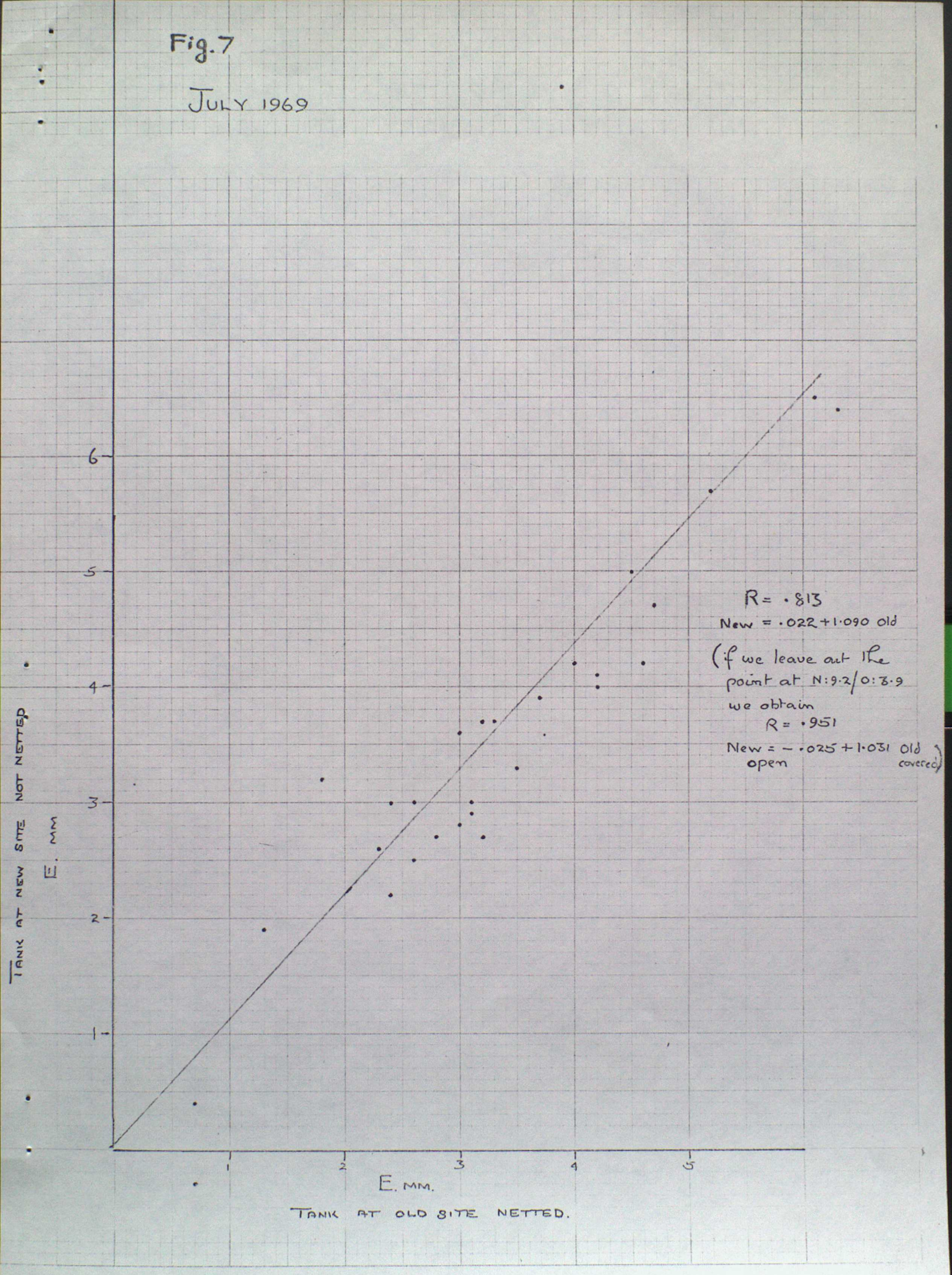
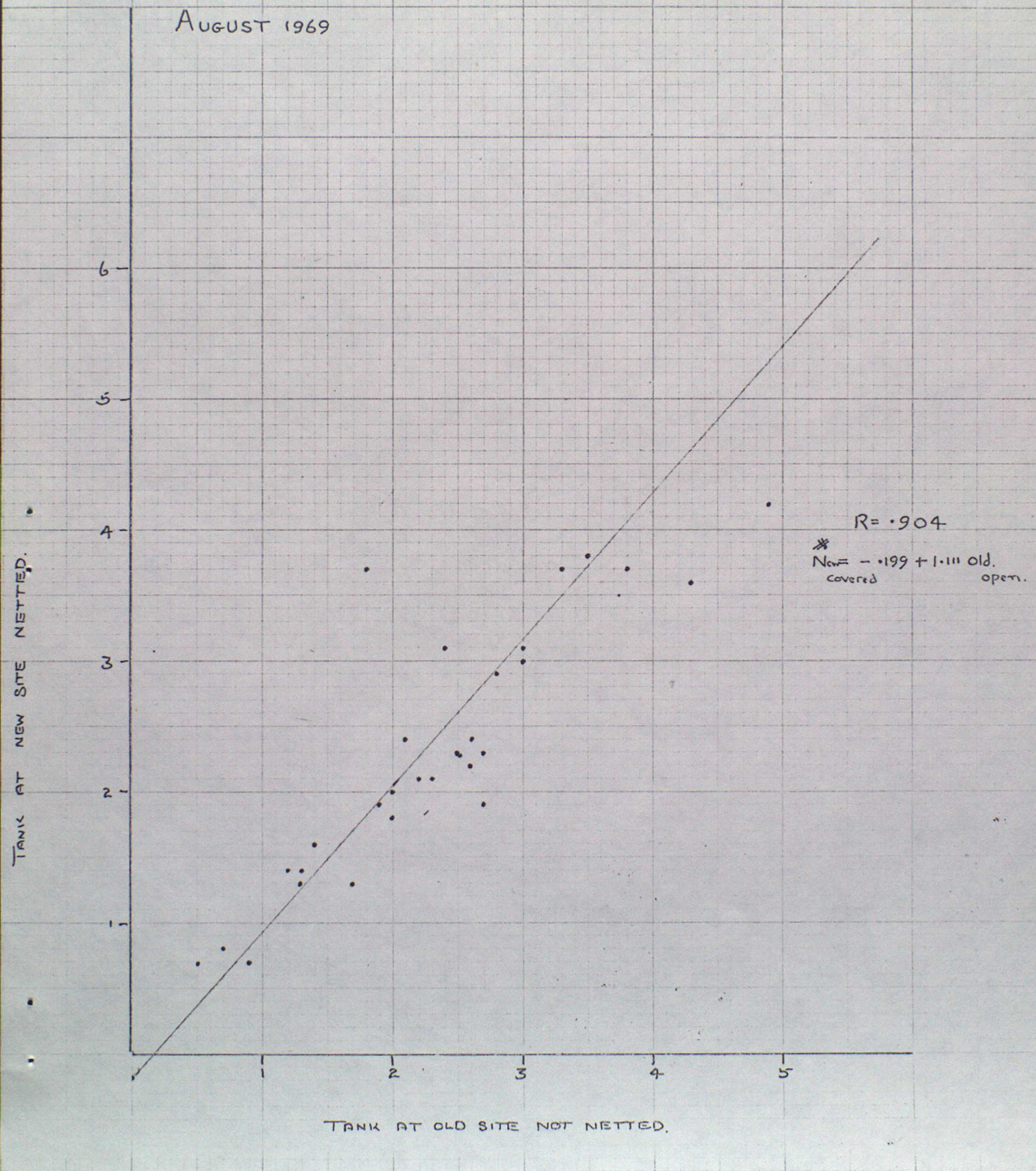


Fig. 8.


AUGUST 1969
R = ·904
* New = −·199 + 1·111 old.
covered open.
TANK AT NEW SITE NETTED.
TANK AT OLD SITE NOT NETTED.
1
2
3
4
5
6