INTERSERVICE RADIO PROPAGATION LABORATORY
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C.
Organized under Joint U.S. Communications Board

Issued
20 March 1947

THE INTERPRETATION OF RECORDED VALUES OF fEs

Recorded values of fEs, the upper-limit frequency for vertical-incidence reflection of radio waves from regions of sporadic ionization at E-layer heights, are extremely variable, both in time and space. Generally speaking, diurnal, seasonal, and secular changes at any ionosphere station seem determined only within limits of precision which are compatible with day-to-day variability. However, there have sometimes appeared consistent discrepancies in data reported from various stations, which are not easily explained by related geophysical, solar, or cosmic variations. In order to determine whether these discrepancies were caused by erroneous interpretation of records, varying equipment characteristics, or any other physical phenomena, consideration was given to the distribution of recorded fEs at each station, at each hour throughout the day, for the months of December 1944, April 1945, and June 1945, these being representative of winter solstice, equinox, and summer solstice conditions.

The distribution of fEs at any stated hour, season, and place, is, in general, slightly skewed, but so poorly defined that the calculation of the ordinary statistics, which have poor efficiency in describing such distributions, and are thus often misleading, seems not worth while. Simple inspection of mass plots of these data, however, reveal several interesting facts which afford ample cause for many of the discrepancies noted. These mass plots of fEs from various reporting stations for the months under consideration are here presented as Figs. 1 through 55.

Three facts may be readily noted by inspection of these mass plots:

1. Change of equipment characteristics, probably those of relative power emission and sensitivity of reception, throughout the frequency range, are sometimes of great importance in controlling the recorded value of fEs. This is particularly true in the cases of stations at Fairbanks, Alaska; Huancayo, Peru; and Watheroo, W. Australia. All three stations use practically identical equipment, where the apparatus variations accompanying the change of frequency bands at 1.6, 3.3, and 5.6 Mc cause marked maxima in the distribution of fEs at, or just below, these values. Similar, although for less marked, maxima in distribution at fixed frequency values are shown by the data from several other stations.

It is readily apparent that neither median values of fEs nor percentages of time occurrence of fEs above stated frequency values, obtained from these data, have great precision. Moreover, although the artificial distortion of the distribution is not as apparent in other cases, the question may well be raised as to the effect of a progressive change in apparatus characteristics upon the recorded data. Several tests comparing data recorded by means of two different sets of equipment situated near each other have indicated that probable discrepancies are not extremely large, but more thorough tests, it would seem, are highly desirable.

2. The slight distribution maxima of fEs occurring near the close distribution of f^oE suggest that regular E-layer reflections, when the cusp indicating the E-layer critical frequency has disappeared through absorption, may sometimes be recorded as fEs. This is particularly indicated in the cases of data from Great Baddow and Washington for June 1945, where the daytime curve of f^oE is continuous with night maxima in distribution of fEs. (In the case of Washington, this effect is only notable during early morning hours, probably because of evening interference in the medium-frequency broadcast band.) Suggestions of this effect are also apparent for several other stations.

3. Maxima in the distribution of fEs at a frequency above the distribution curve of f^oE corresponding to the separation between f^oE and f^xE also suggest that extraordinary-wave reflections from the regular E layer may frequently be recorded as fEs when the cusp indicating f^xE is absorbed. This effect is marked in the data from Great Baddow and San Francisco for April and June 1945, but is also apparent in the data for many other stations.

Of the above possibilities of distortion of median values of fEs, or of percentages of time occurrence above a given frequency value, that caused by apparatus characteristics is probably the worst, that caused by scaling extraordinary-wave E-layer reflections as fEs next, as a cause of error. Errors due to the latter cause, however, are insignificant for nighttime percentages of fEs above, say, 3 Mc.

It is suggested that ambiguity arising from the scaling of regular E-layer reflections as fEs could be largely avoided by the adoption of two symbols, one for use when recording fEs within or below the distribution of f^oE for the time and place, in the absence of observed f^oE, and the other for use when recording fEs within or below the distribution of f^xE for the time and place, in the absence of f^xE.

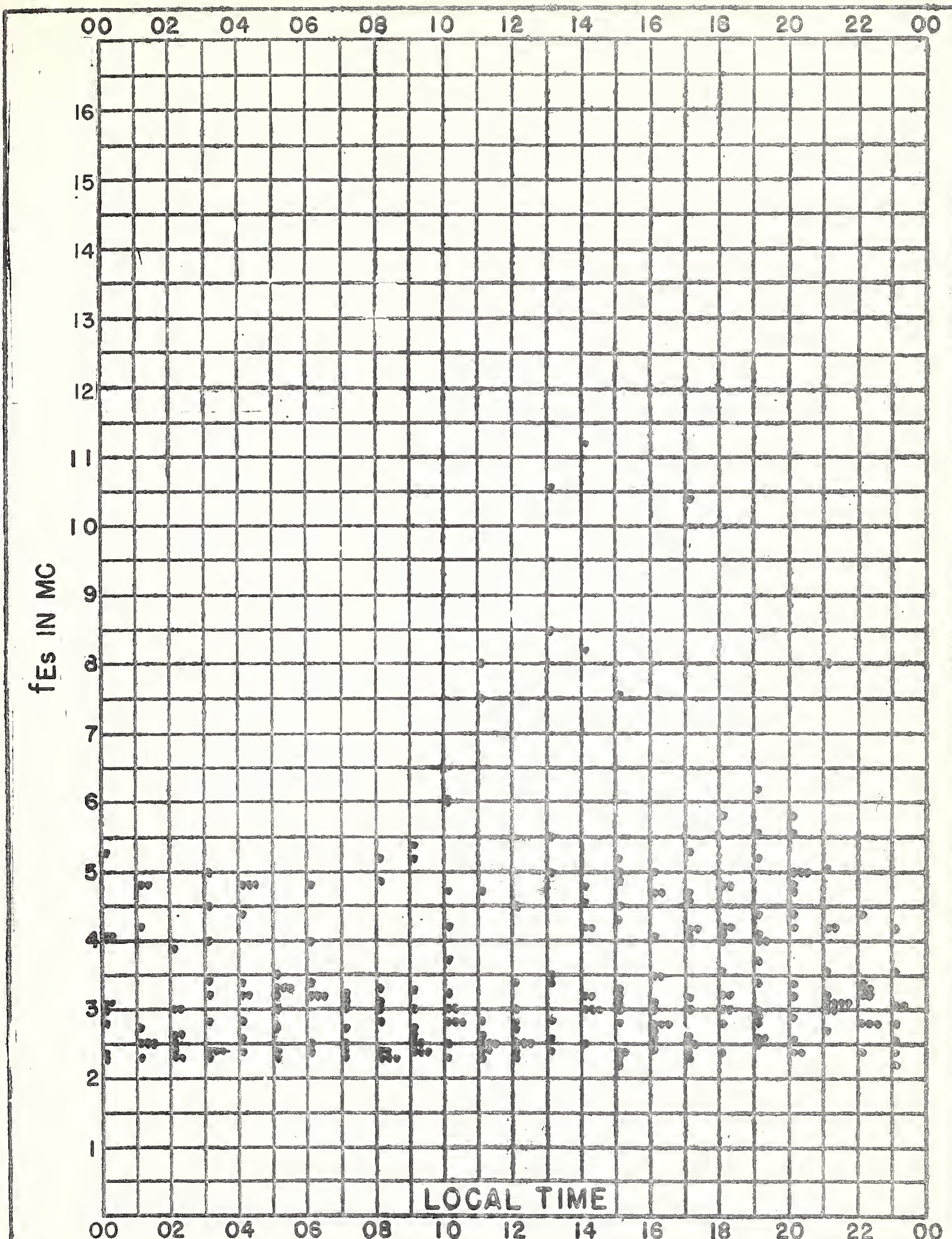

Fig. I. CLYDE, BAFFIN I. • fEs DECEMBER, 1944

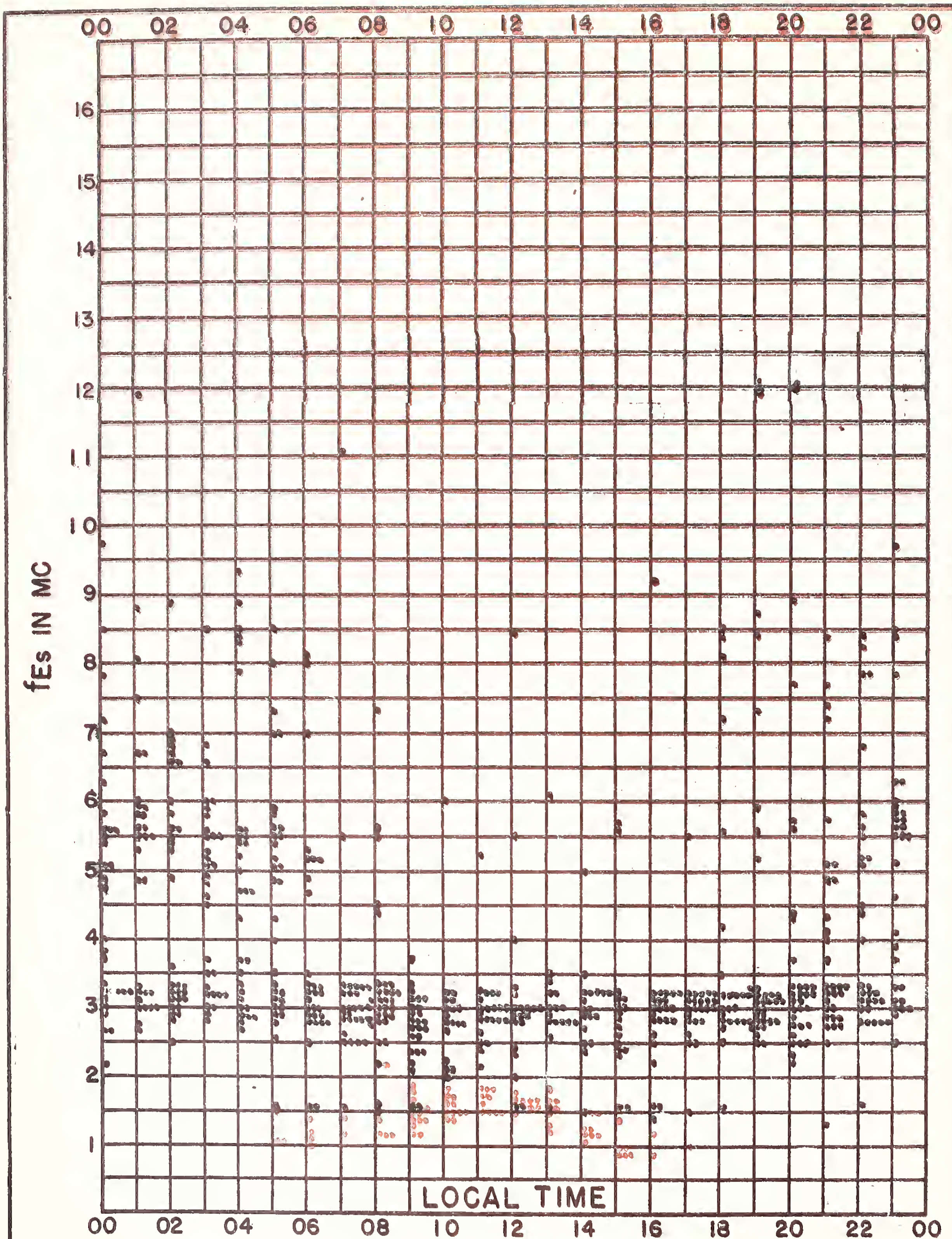

Fig. 2. COLLEGE, ALASKA • fEs • f°E DECEMBER, 1944

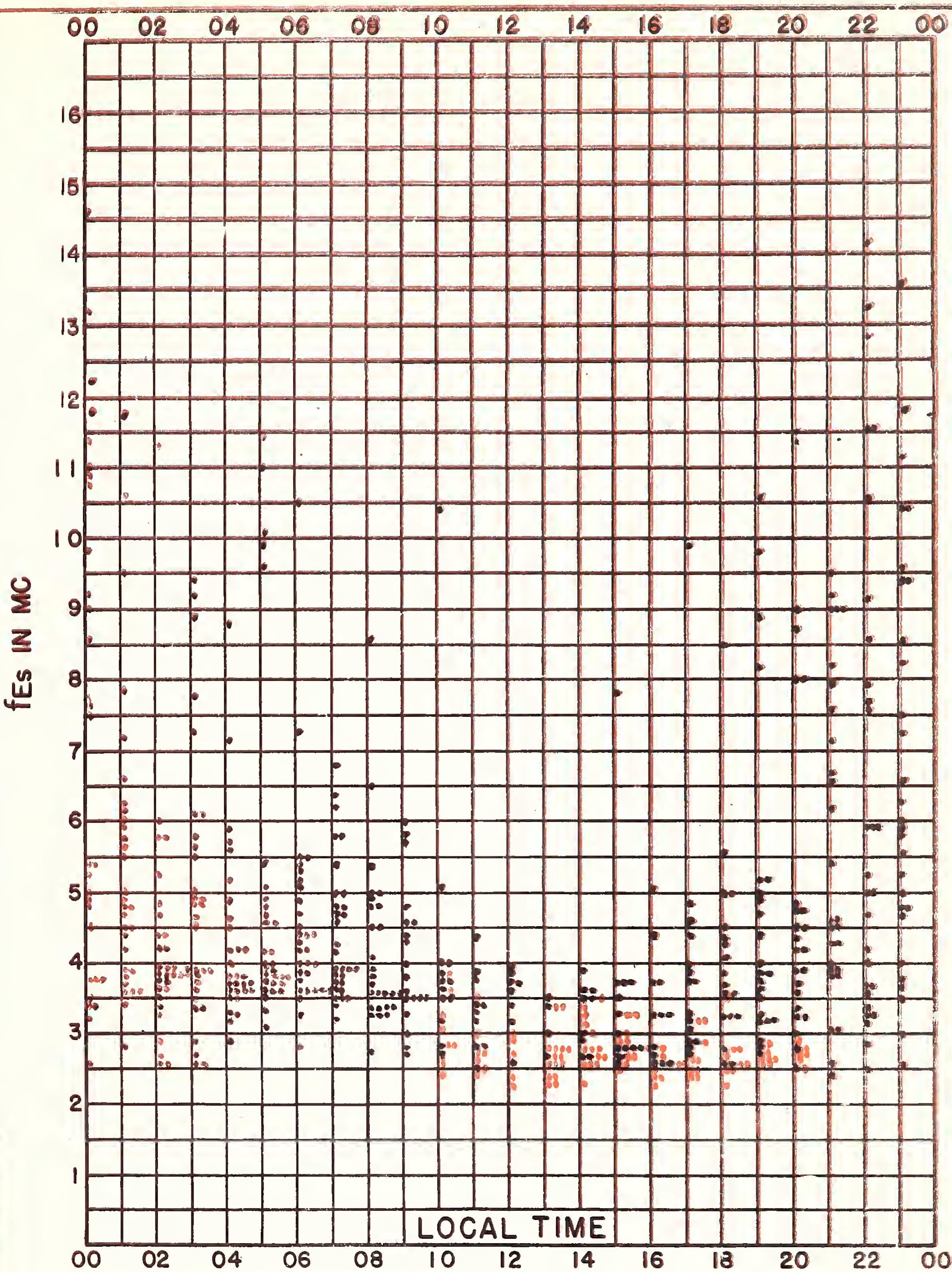

Fig. 3. CHURCHILL, CANADA • f_{Es} • f^oE DECEMBER, 1944

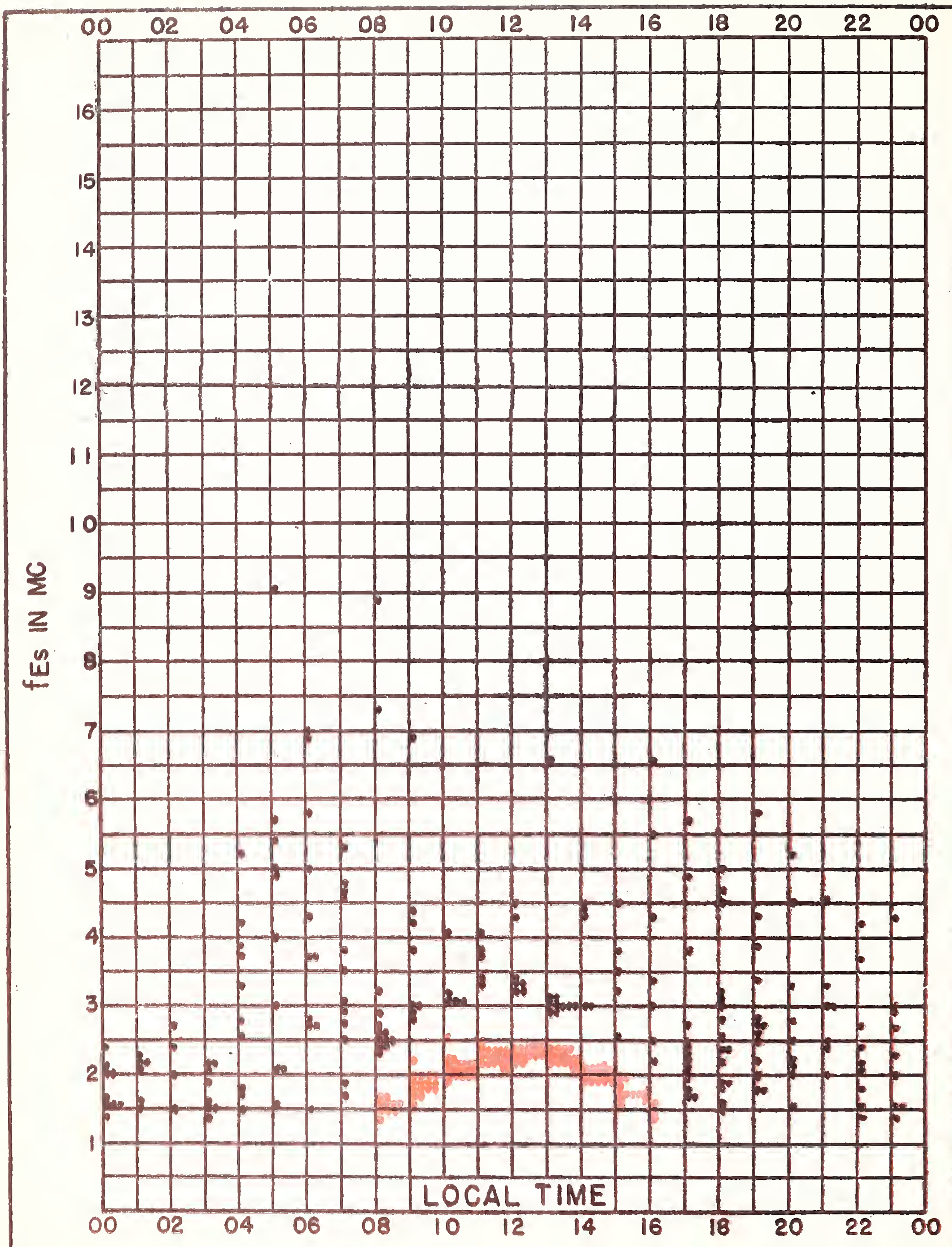

Fig. 4. GREAT BADDOW, ENGLAND DECEMBER, 1944

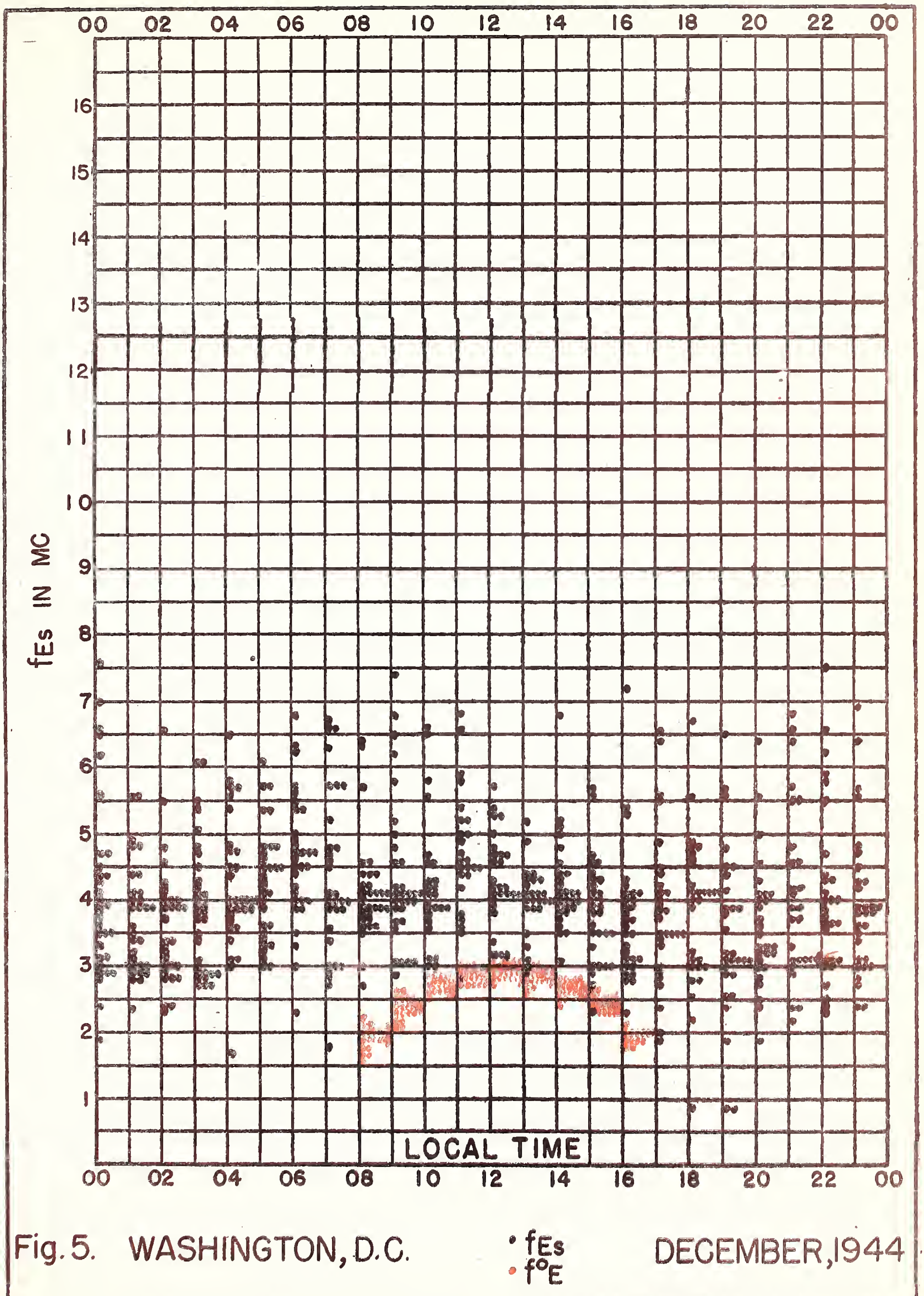

Fig. 5. WASHINGTON, D.C. DECEMBER, 1944

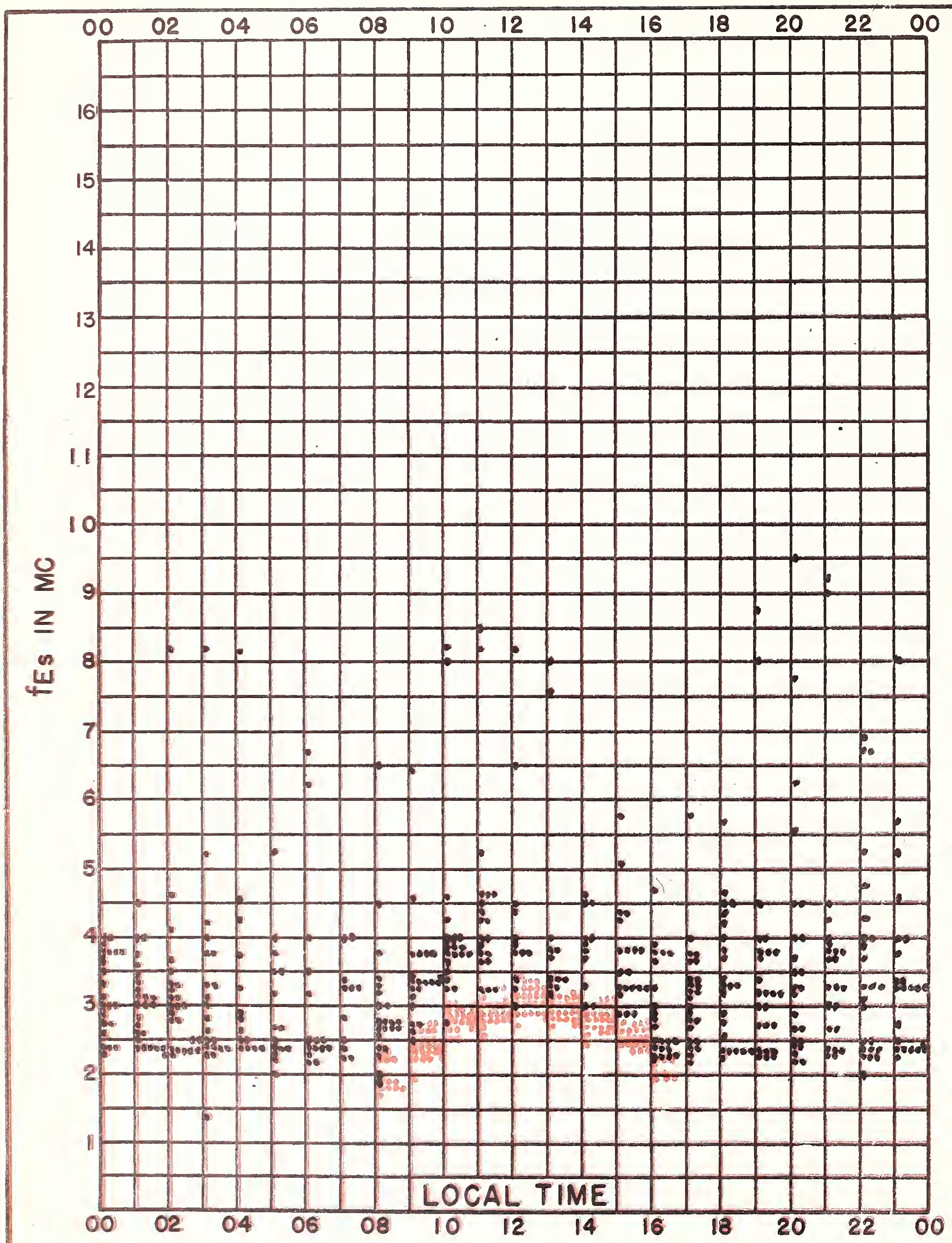

Fig. 6. SAN FRANCISCO, CALIFORNIA • fEs ∘ f°E DECEMBER, 1944

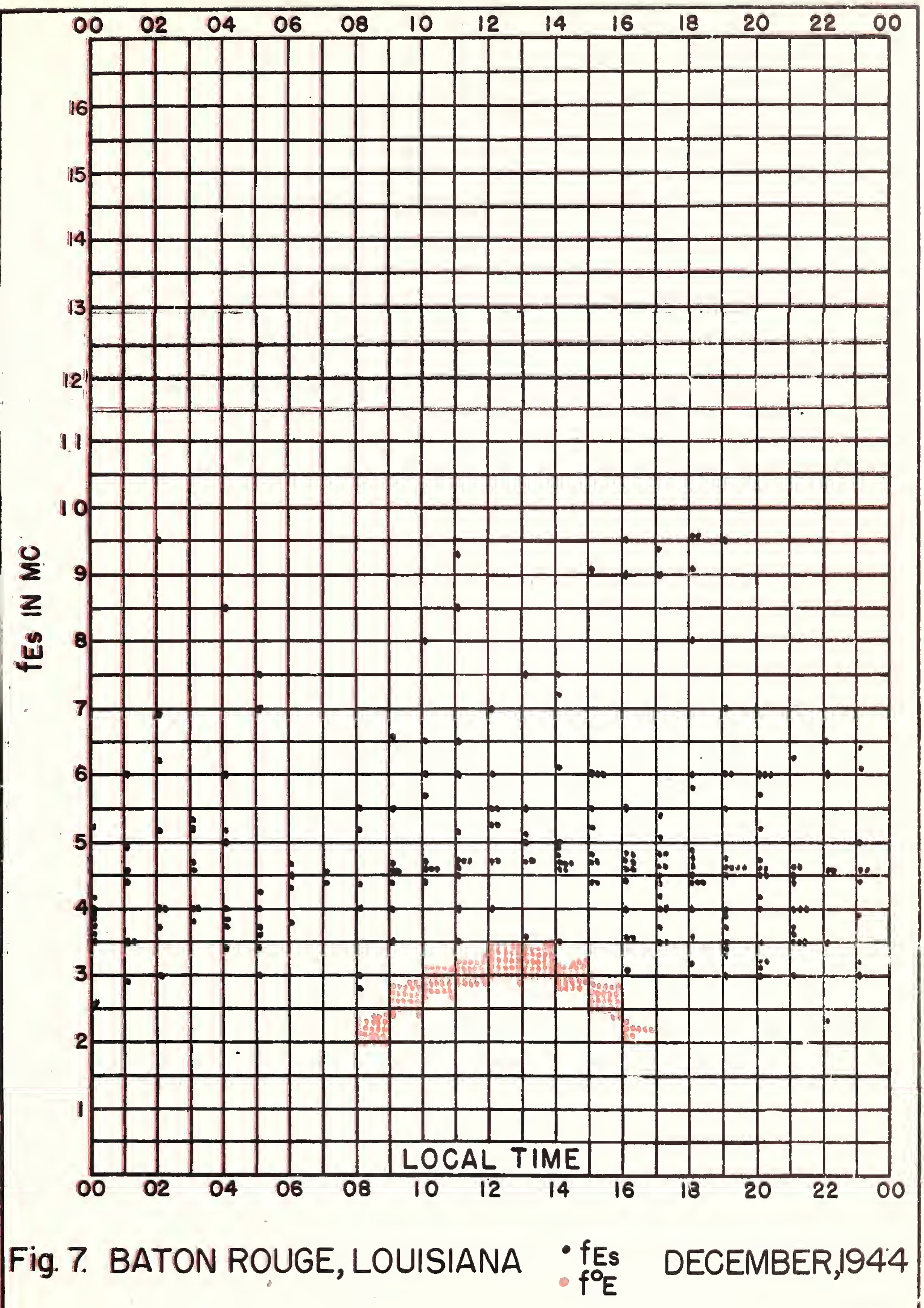

Fig. 7. BATON ROUGE, LOUISIANA DECEMBER, 1944

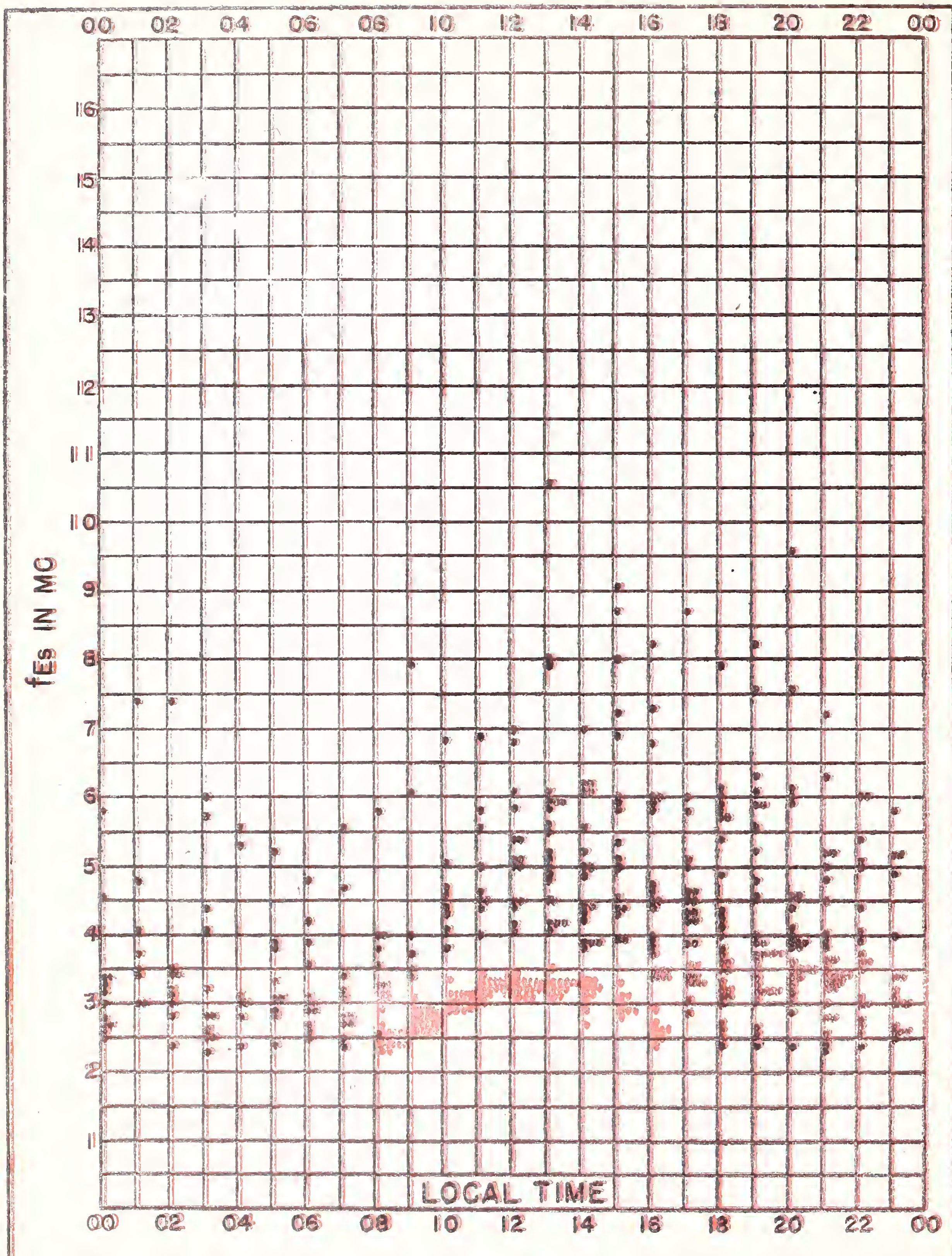

Fig. 8. MAUI, HAWAII • f_{Es} • f^oE DECEMBER, 1944

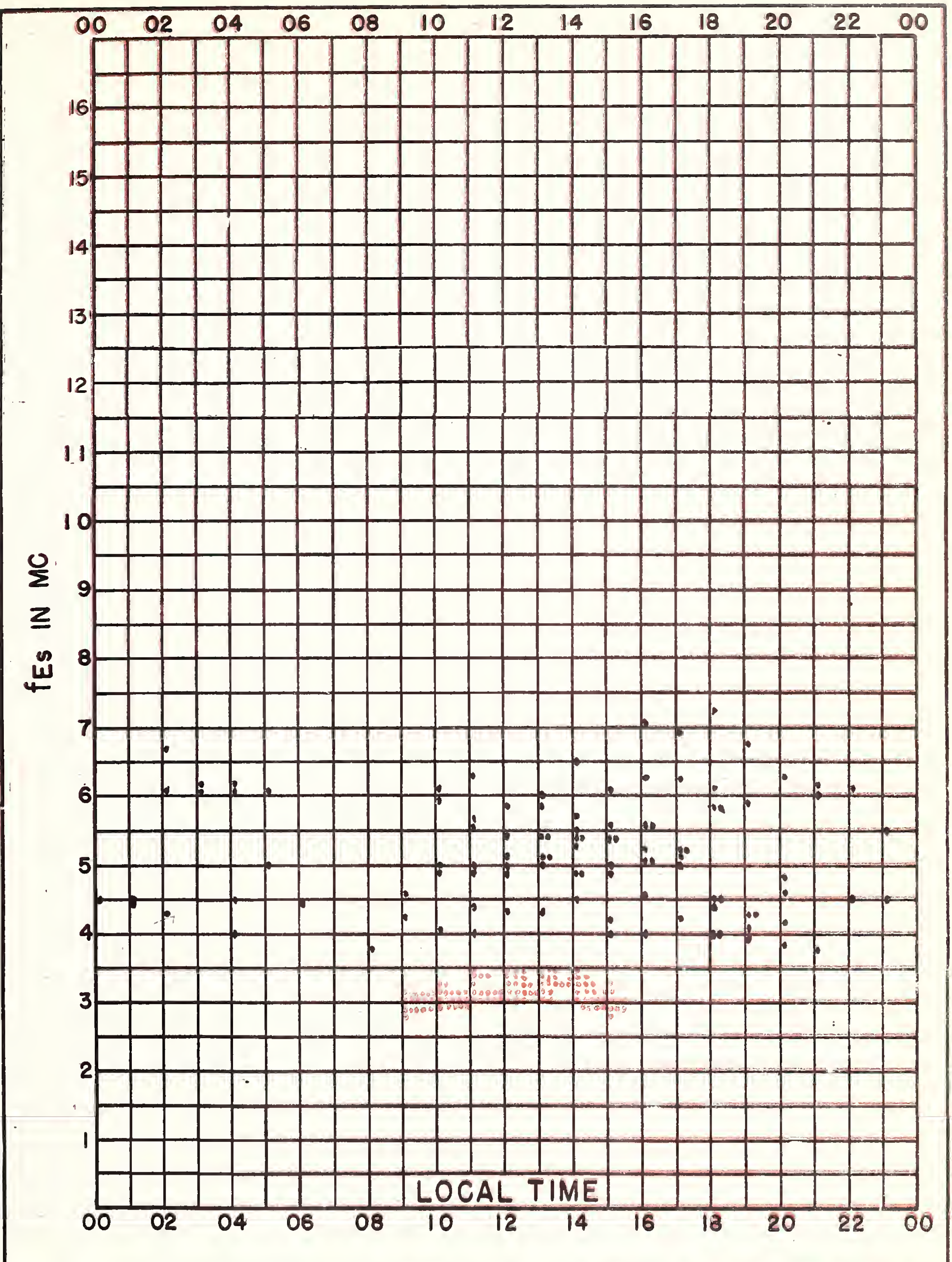

Fig. 9. SAN JUAN, PUERTO RICO • fEs f°E DECEMBER, 1944

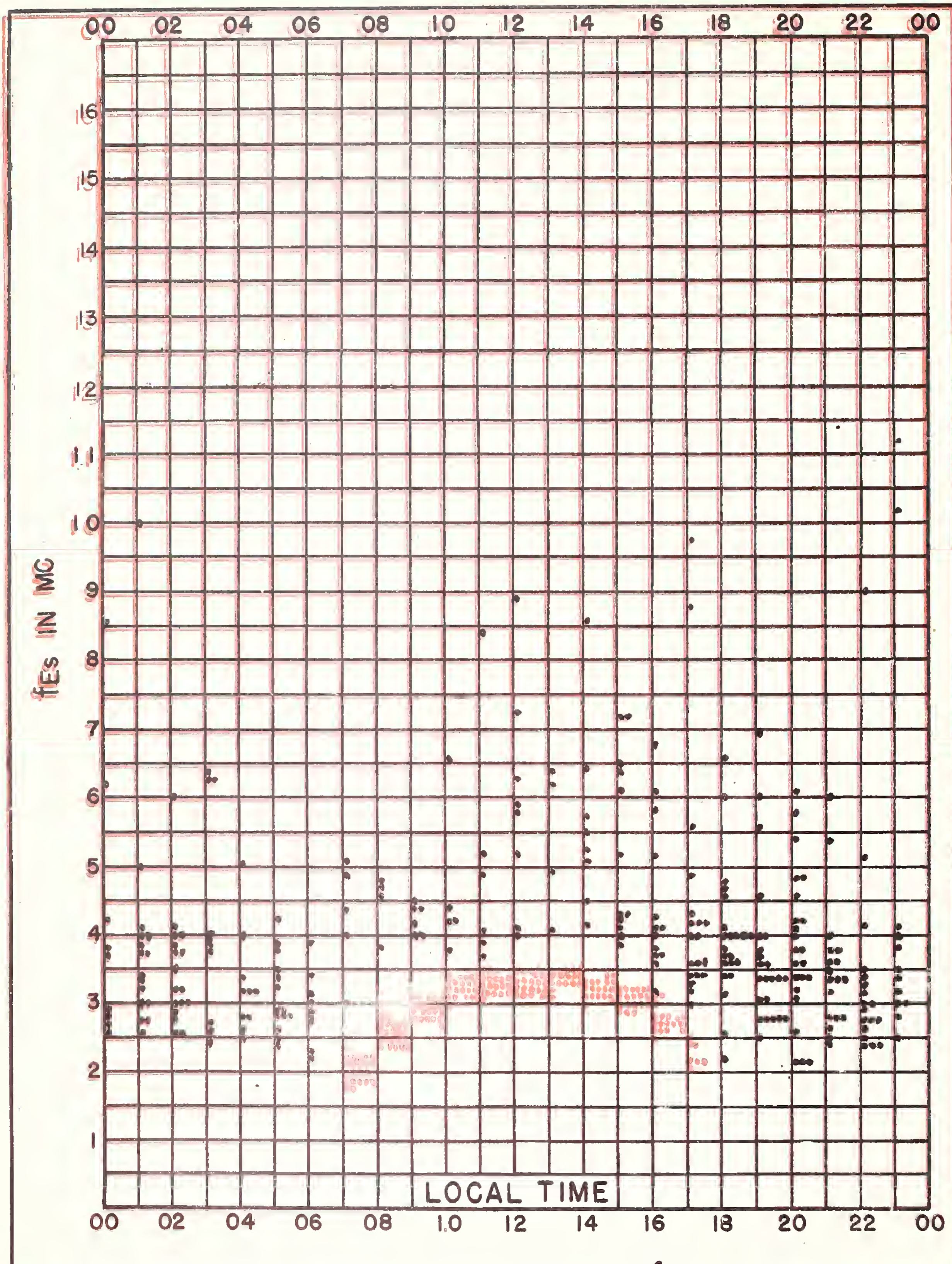

Fig. 10. TRINIDAD, BRIT. WEST INDIES DECEMBER, 1944

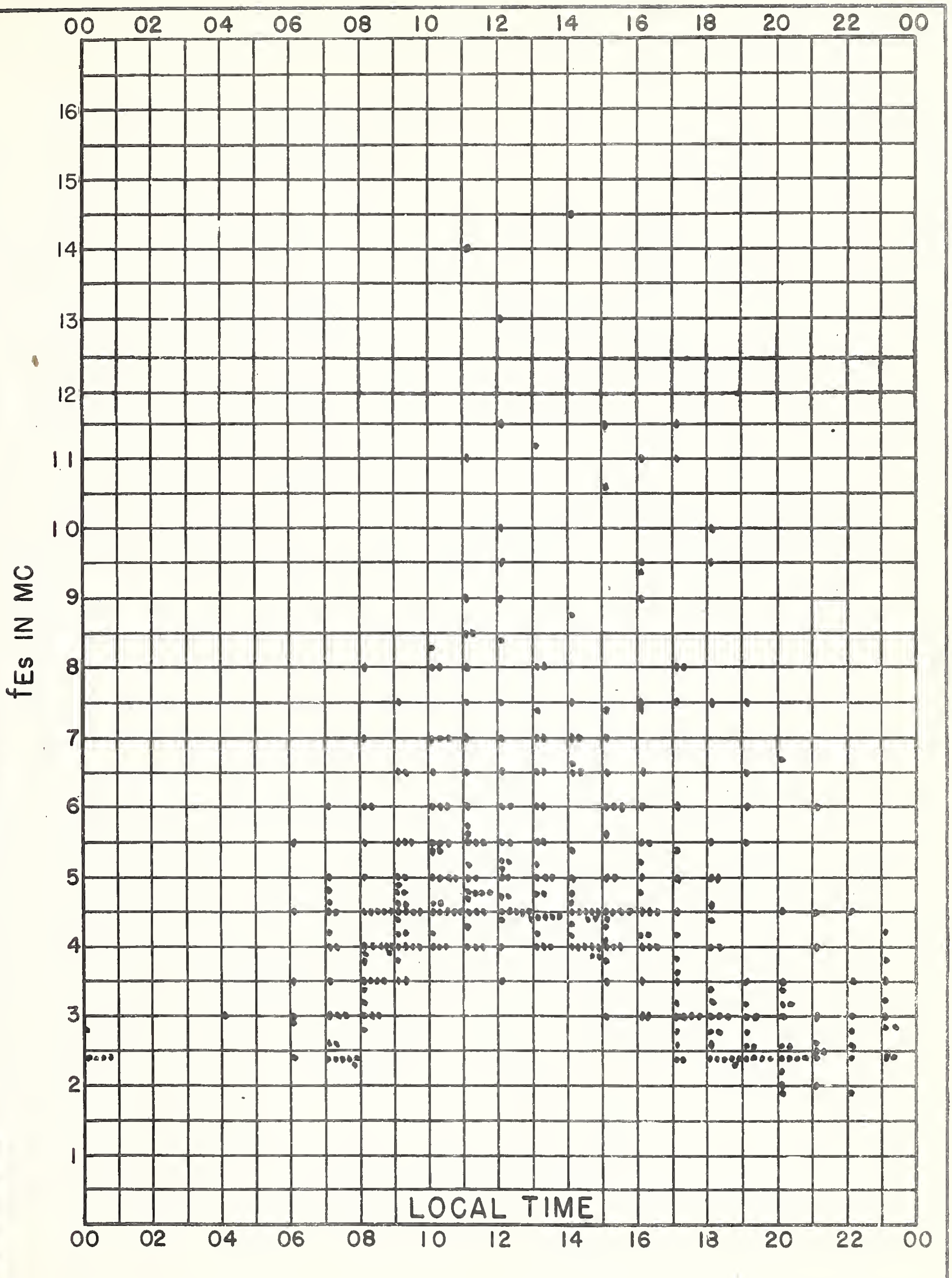

Fig. 11. CHRISTMAS I. • fEs DECEMBER, 1944

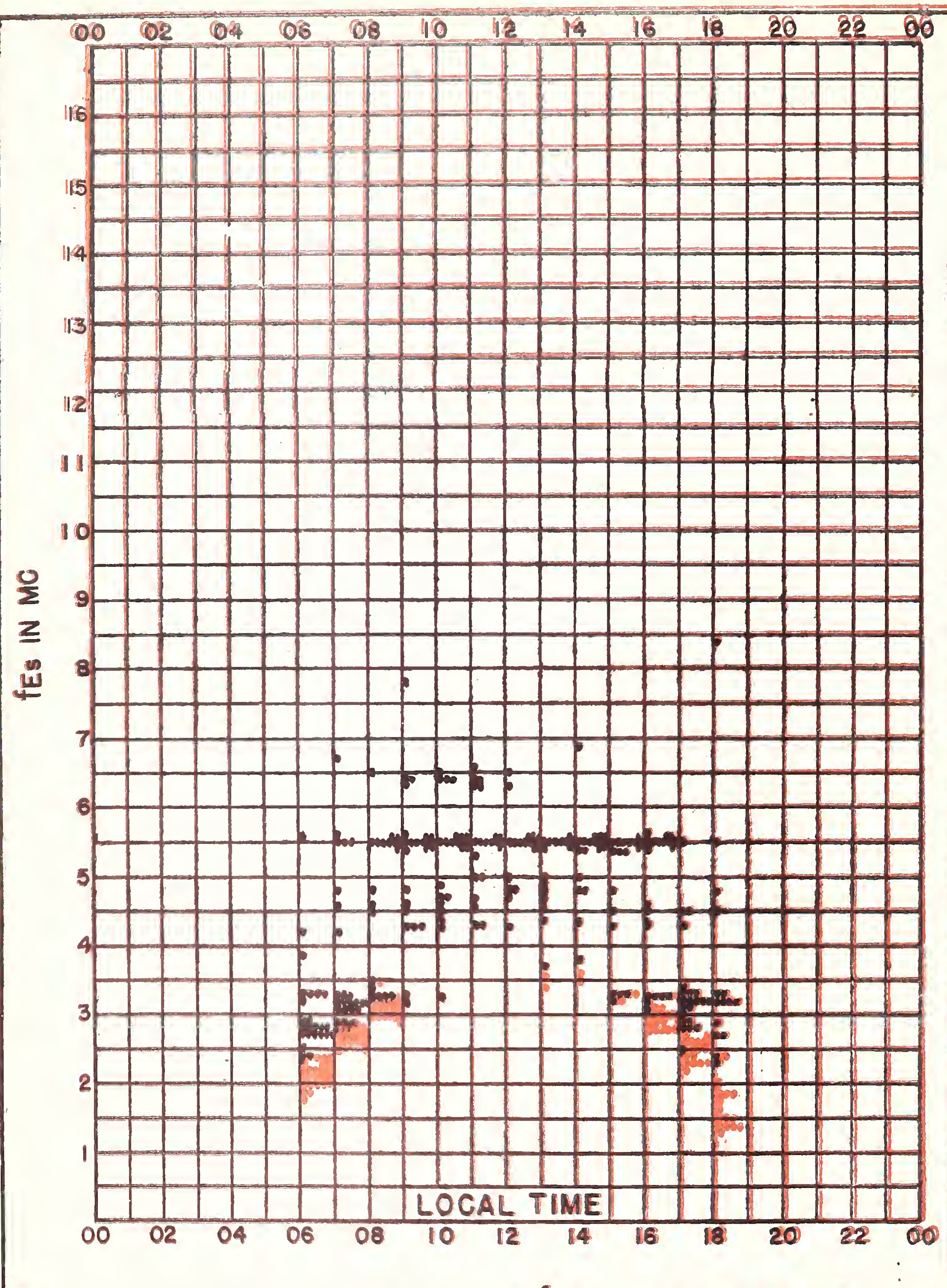

Fig. 12. HUANCAYO, PERU DECEMBER, 1944

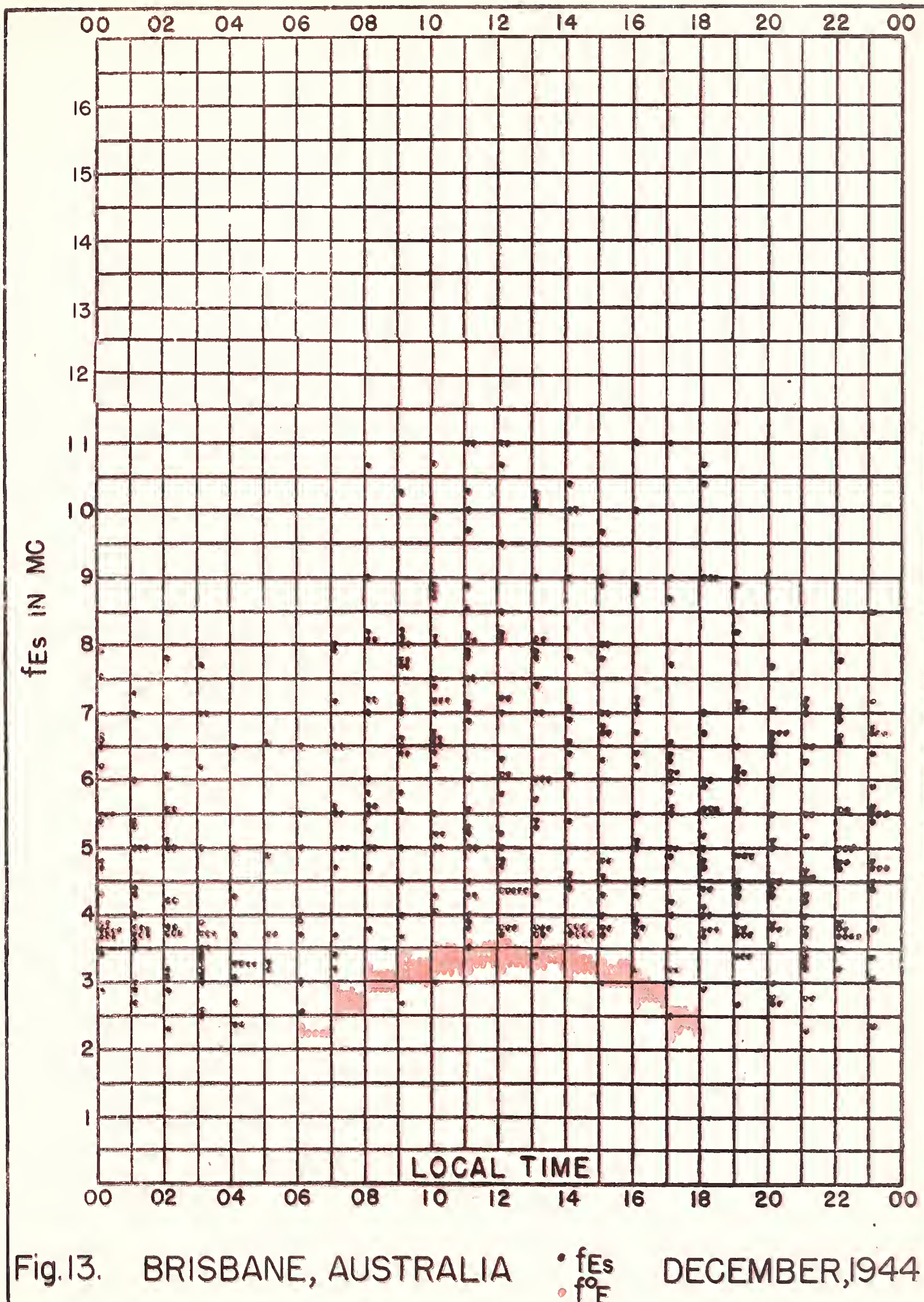

Fig. 13. BRISBANE, AUSTRALIA DECEMBER, 1944

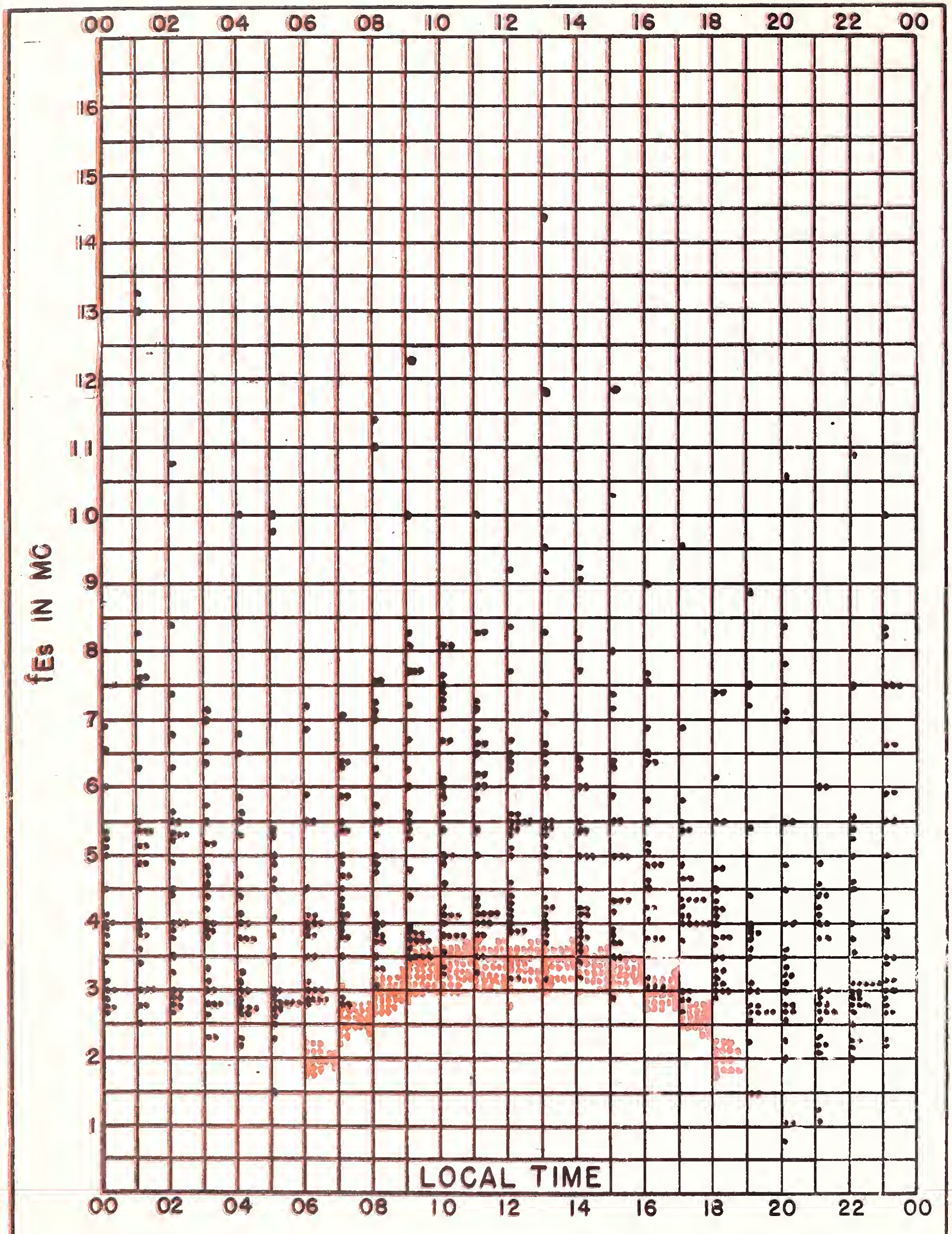

Fig. 14. WATHEROO, W. AUSTRALIA DECEMBER, 1944

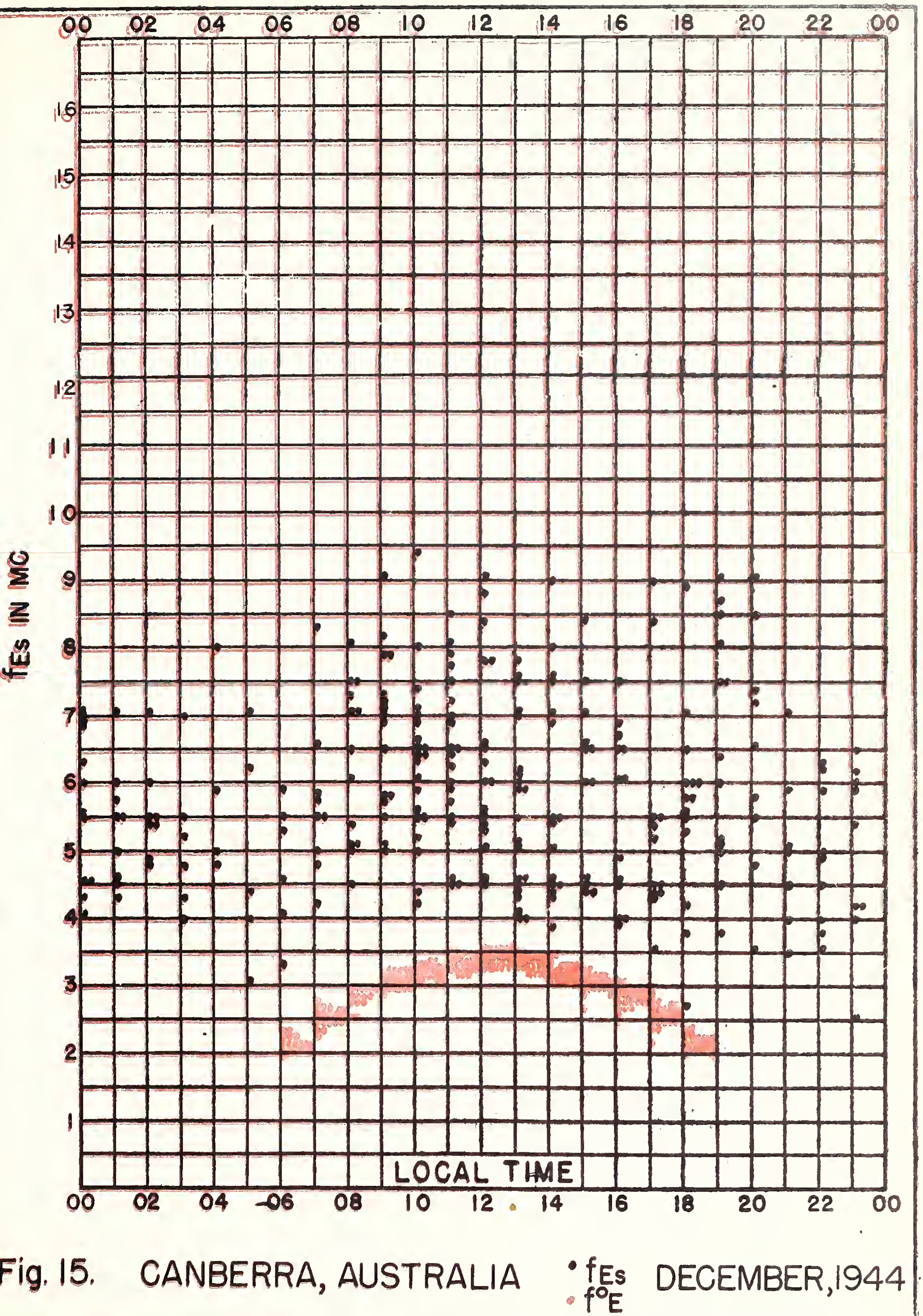

Fig. 15. CANBERRA, AUSTRALIA DECEMBER, 1944

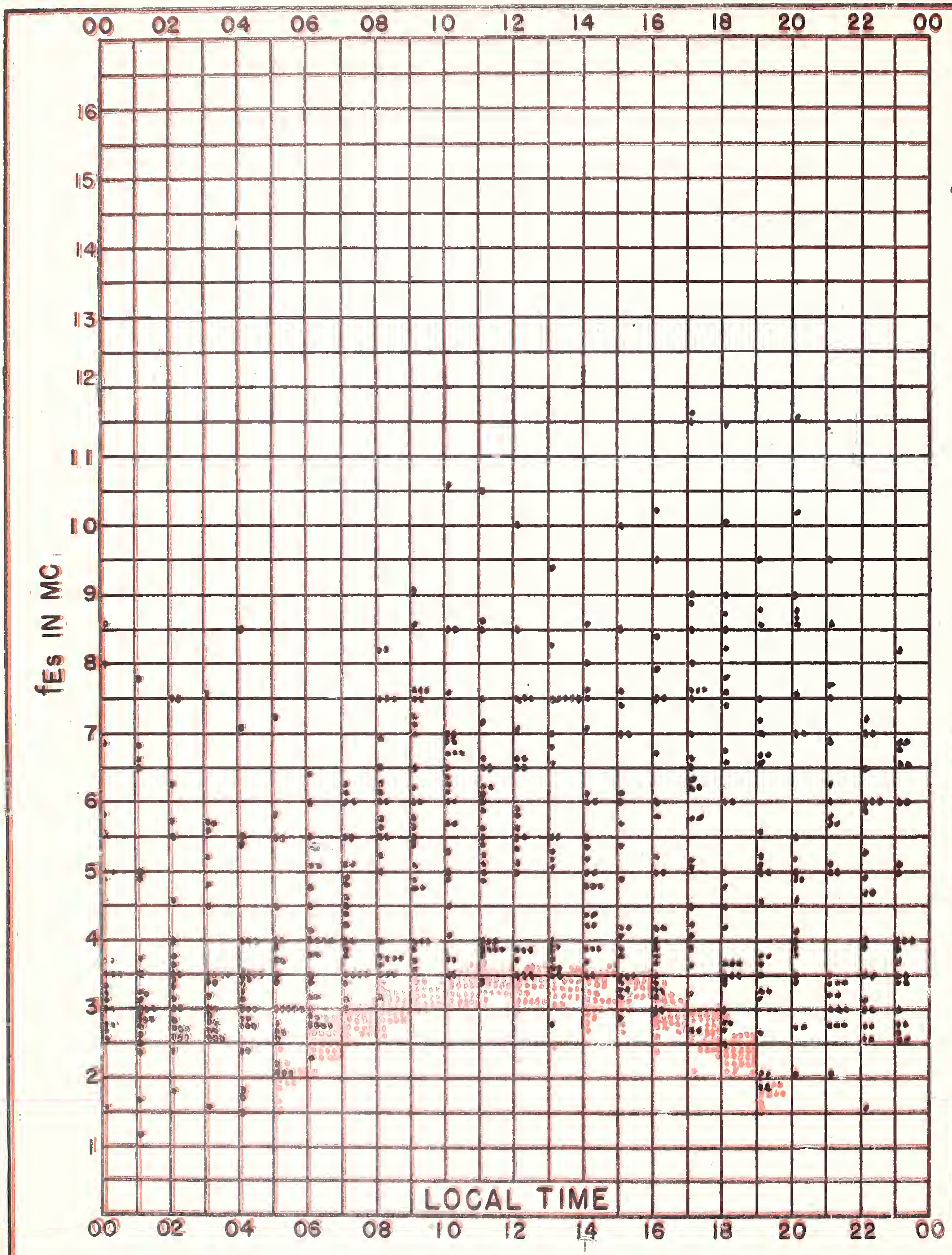

Fig. 16. CHRISTCHURCH, NEW ZEALAND • fEs • f^oE DECEMBER, 1944

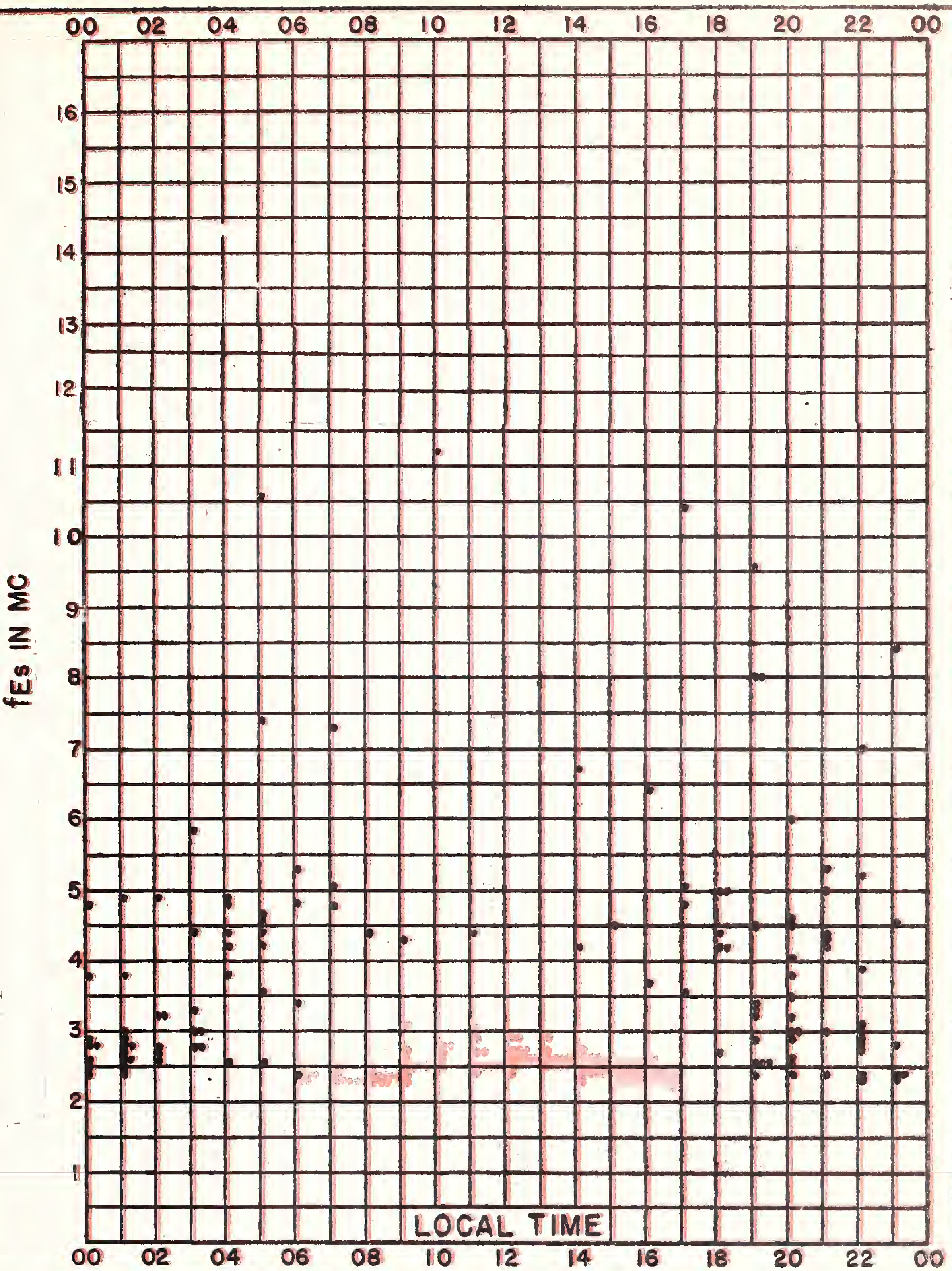

Fig. 17. CLYDE, BAFFIN I. • fEs • f°E APRIL, 1945

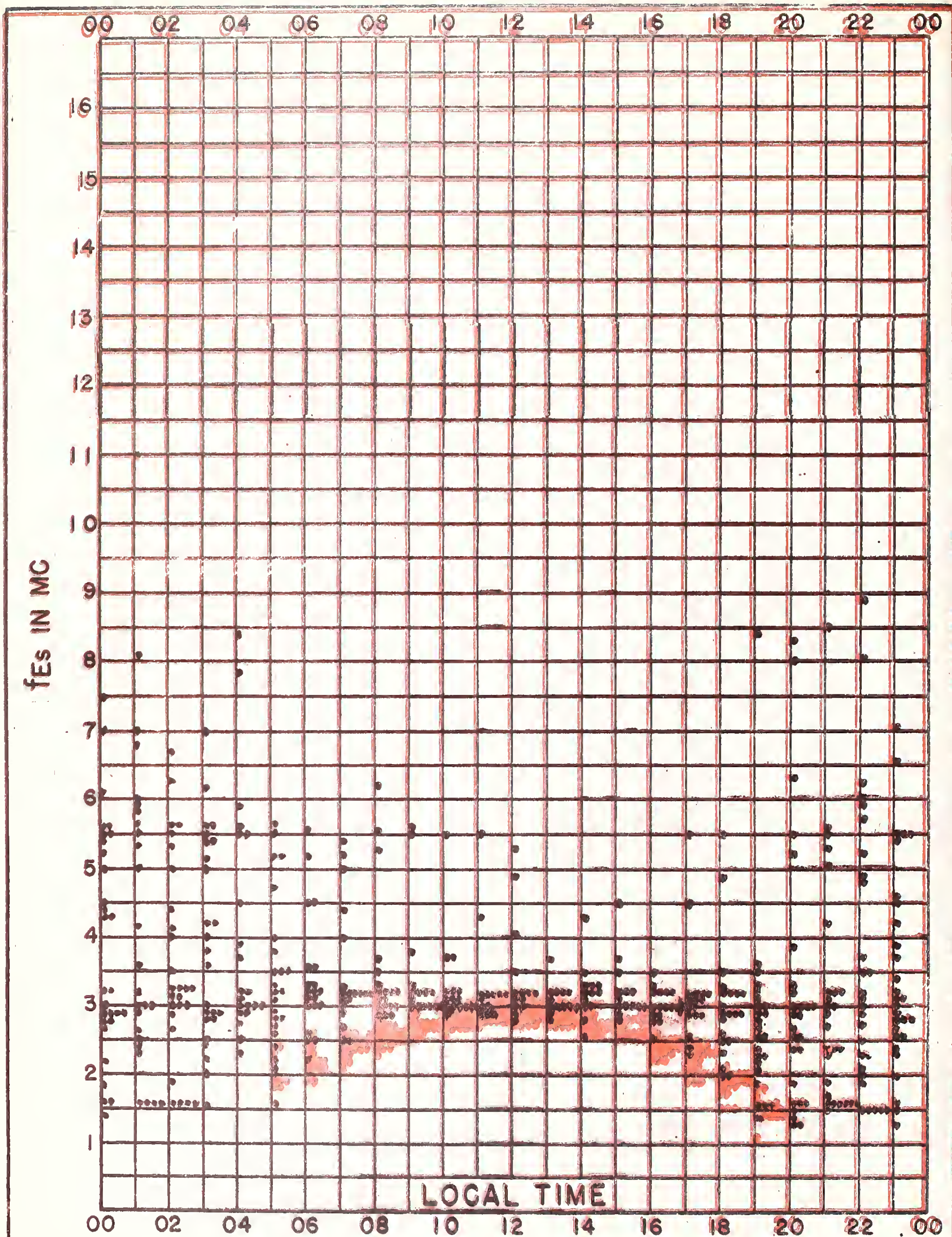

Fig. 18. COLLEGE, ALASKA • f_{Es} • f^{o}_{E} APRIL, 1945

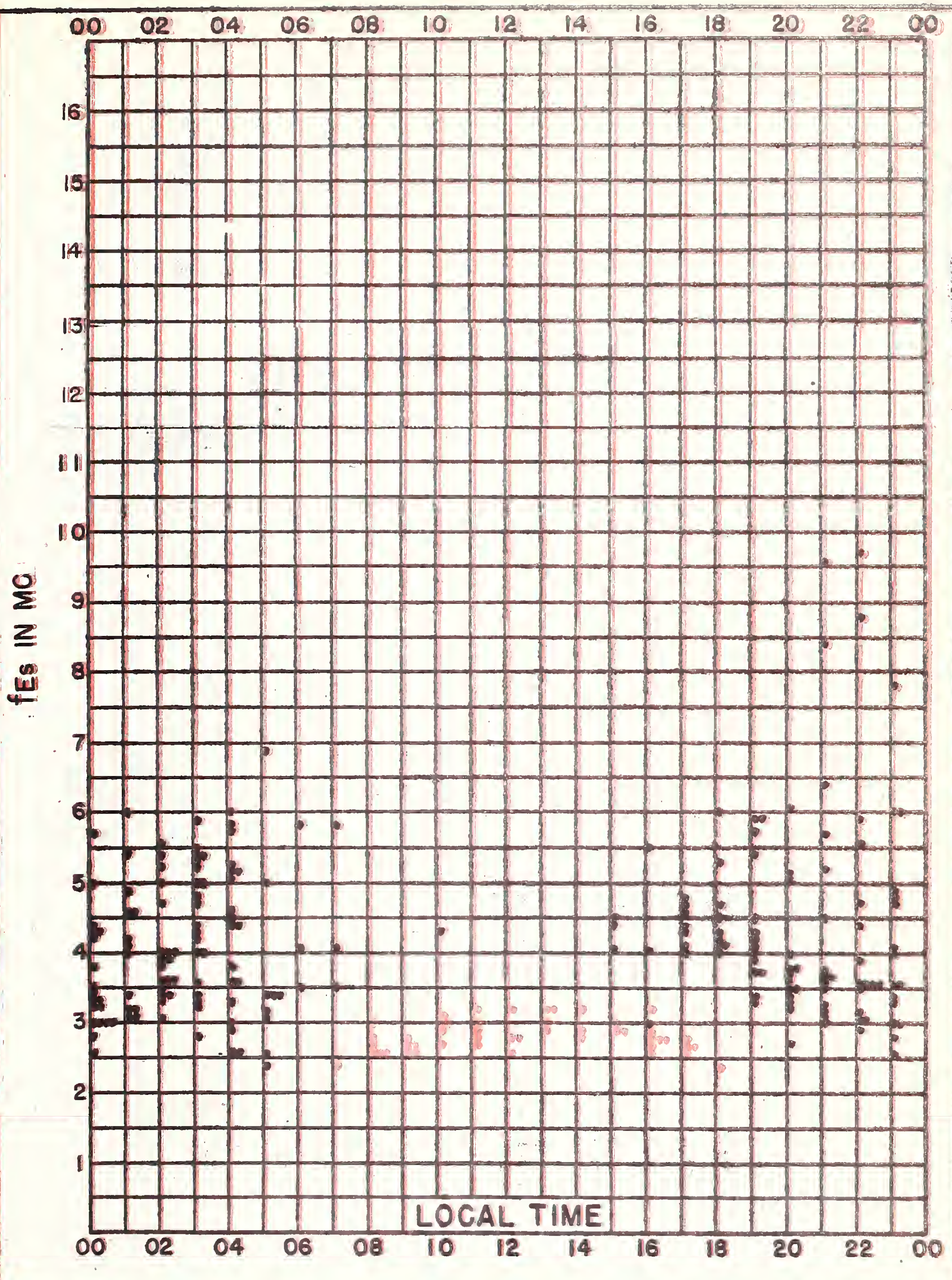

Fig.19. REYKJAVIK, ICELAND • f_{Es} • f^oE APRIL, 1945

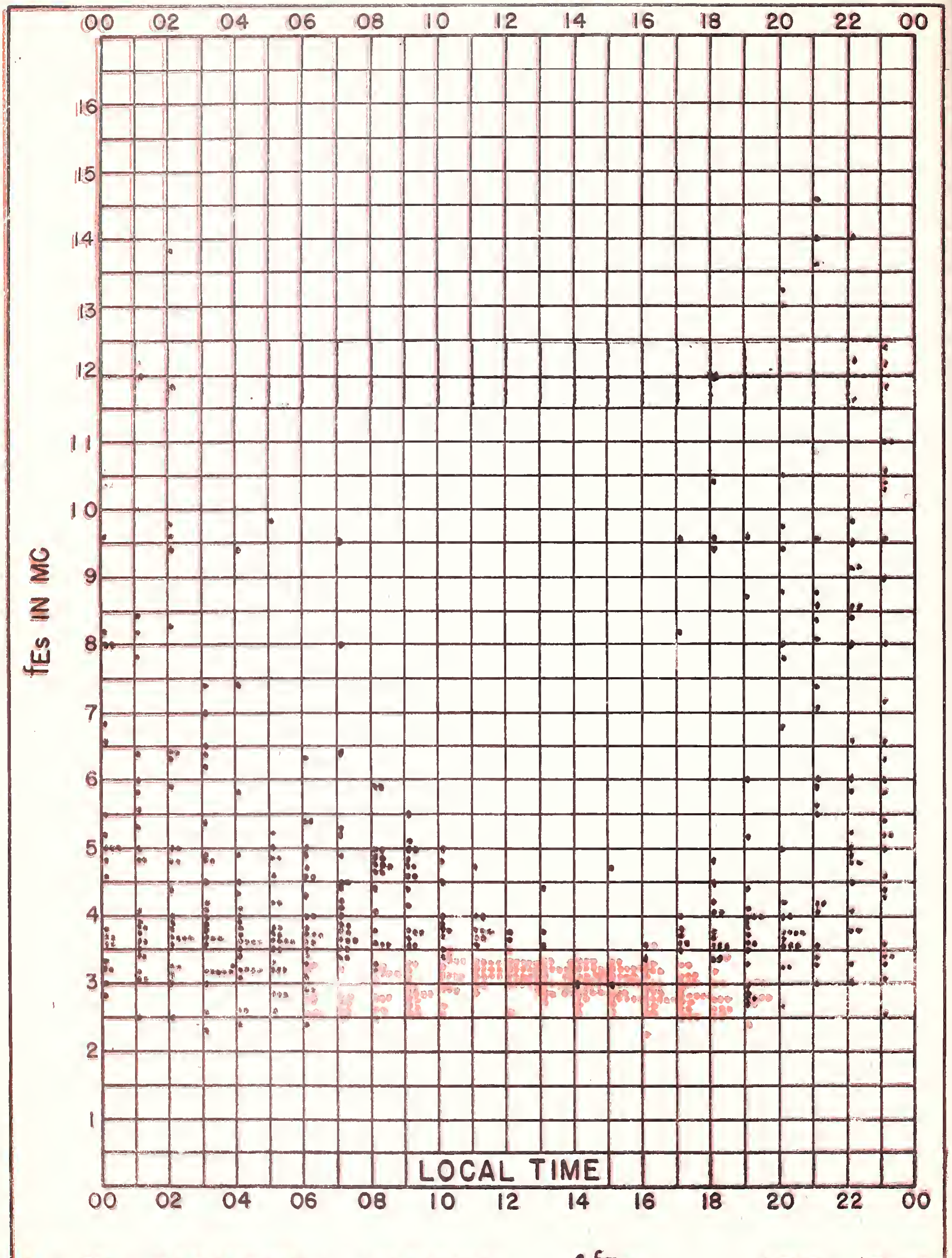

Fig. 20. CHURCHILL, CANADA APRIL, 1945

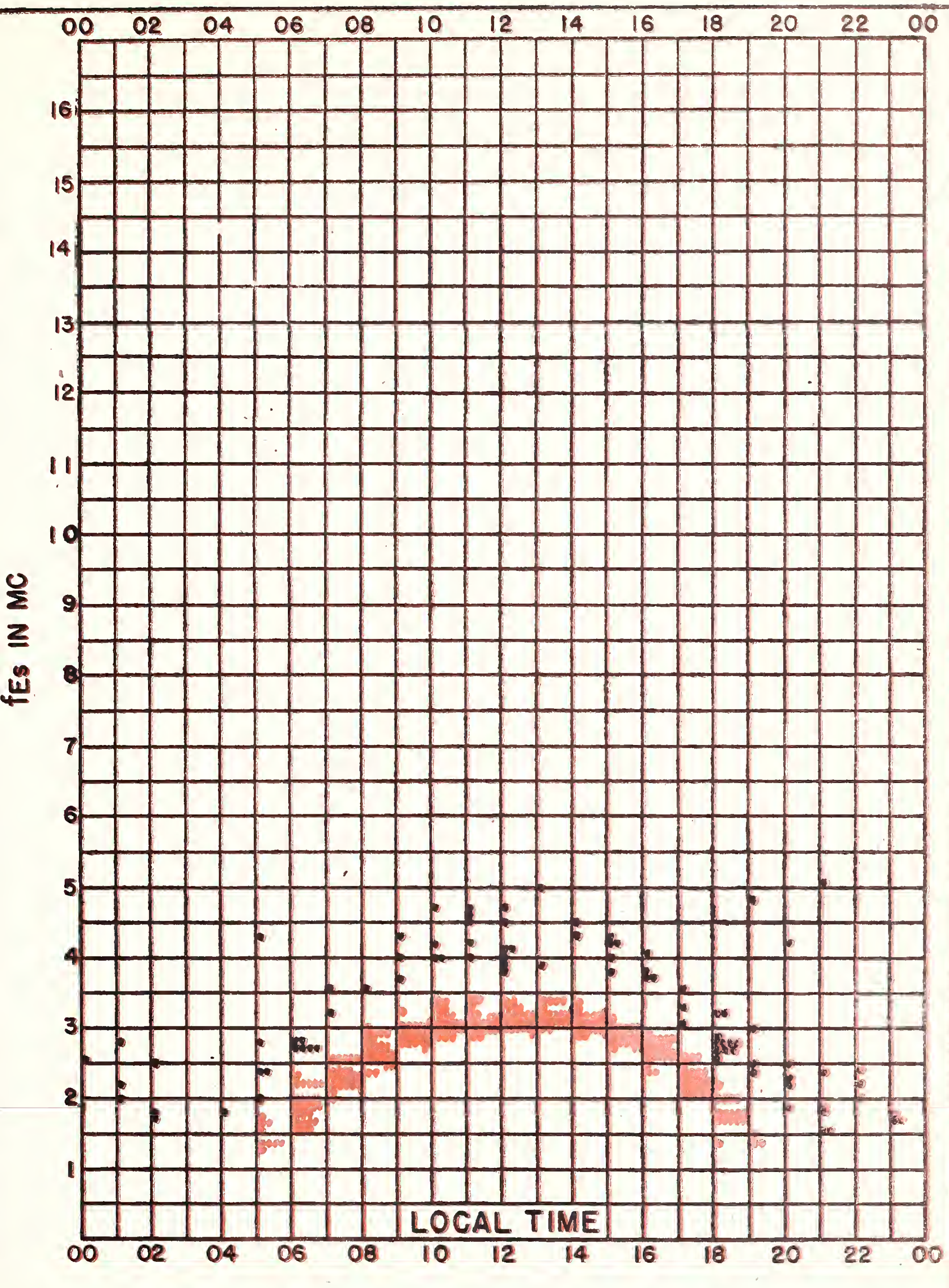

Fig.21. GREAT BADDOW, ENGLAND APRIL, 1945

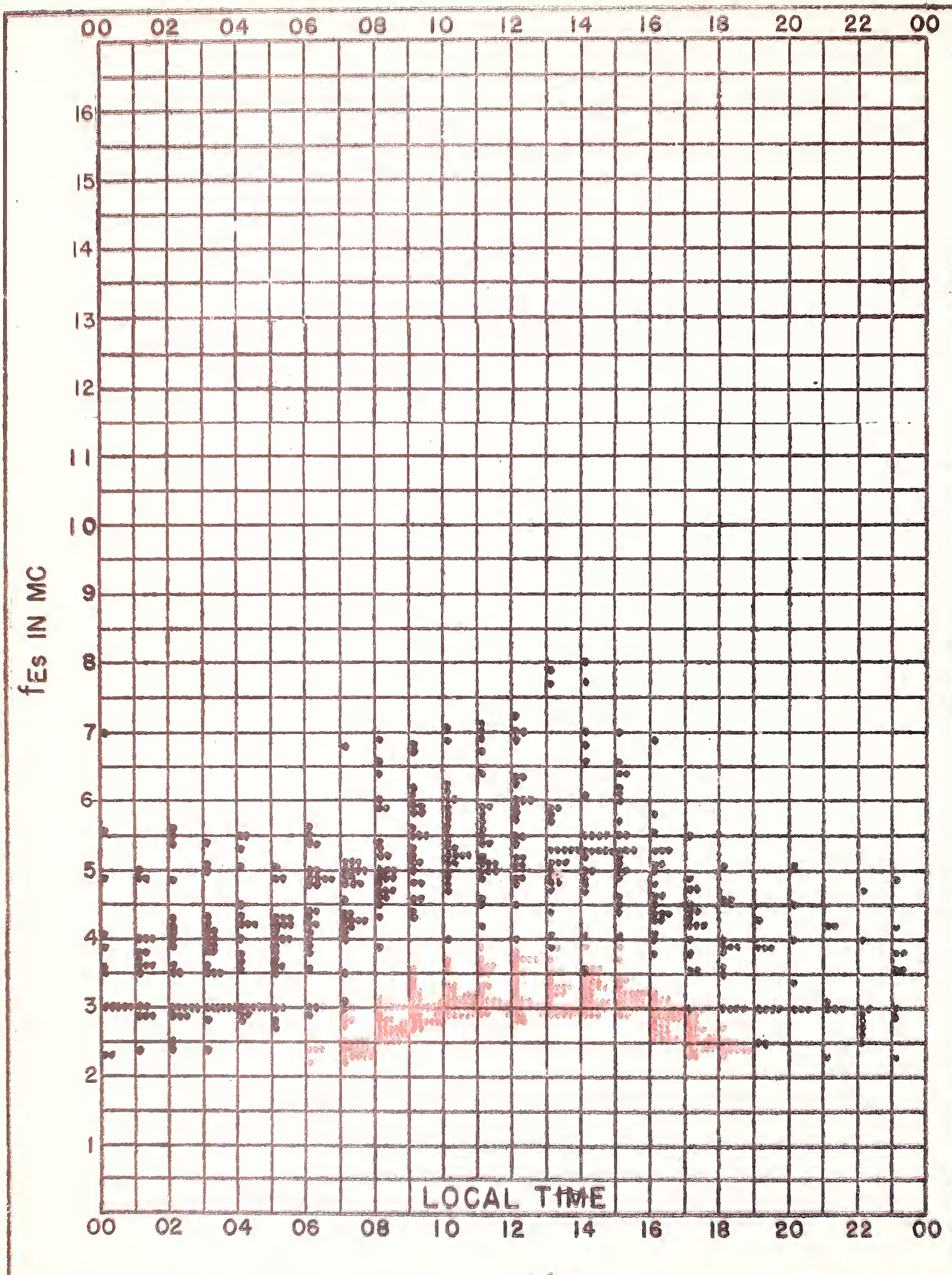

Fig. 22. OTTAWA, CANADA APRIL, 1945

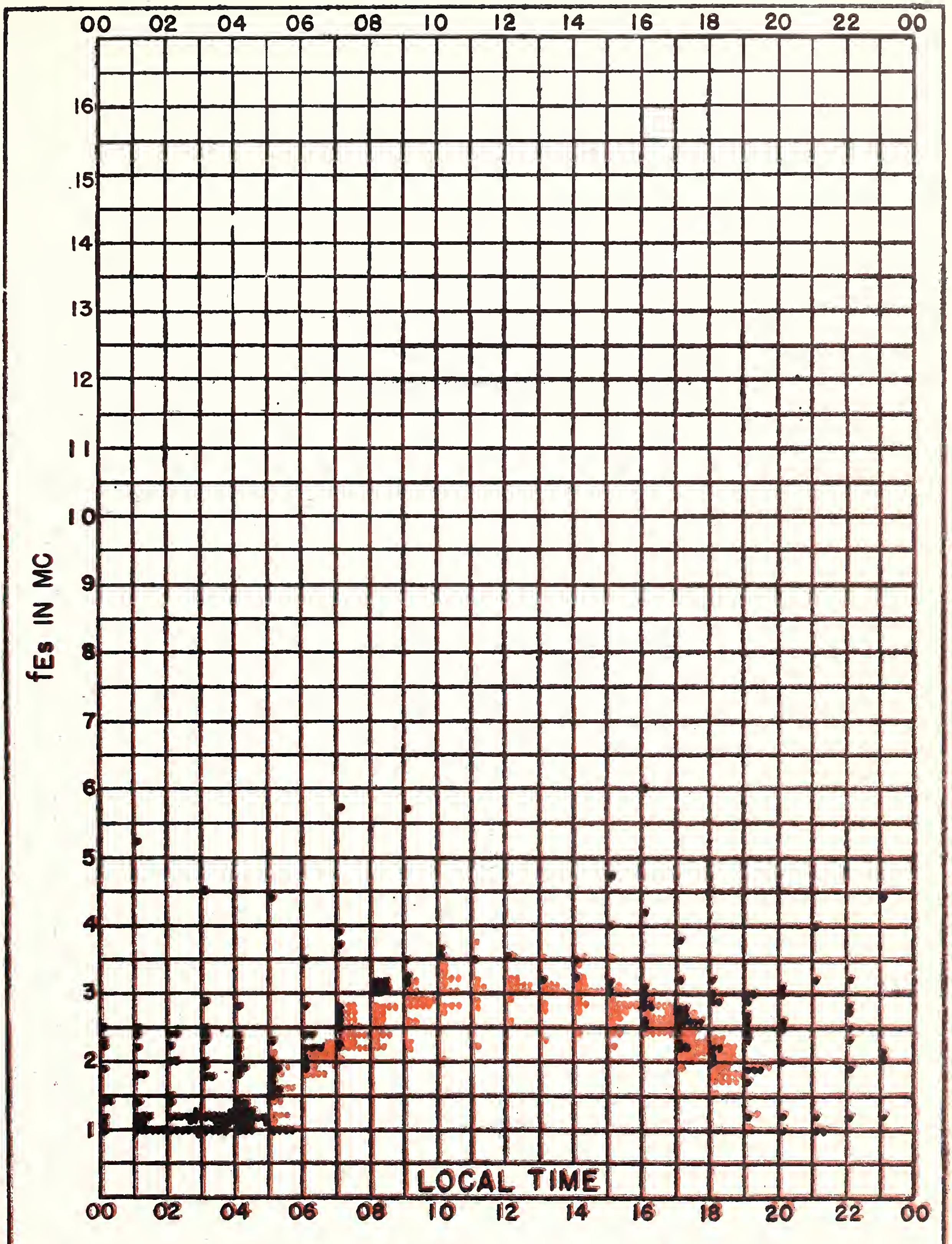

Fig.23. BOSTON, MASSACHUSETTS APRIL, 1945

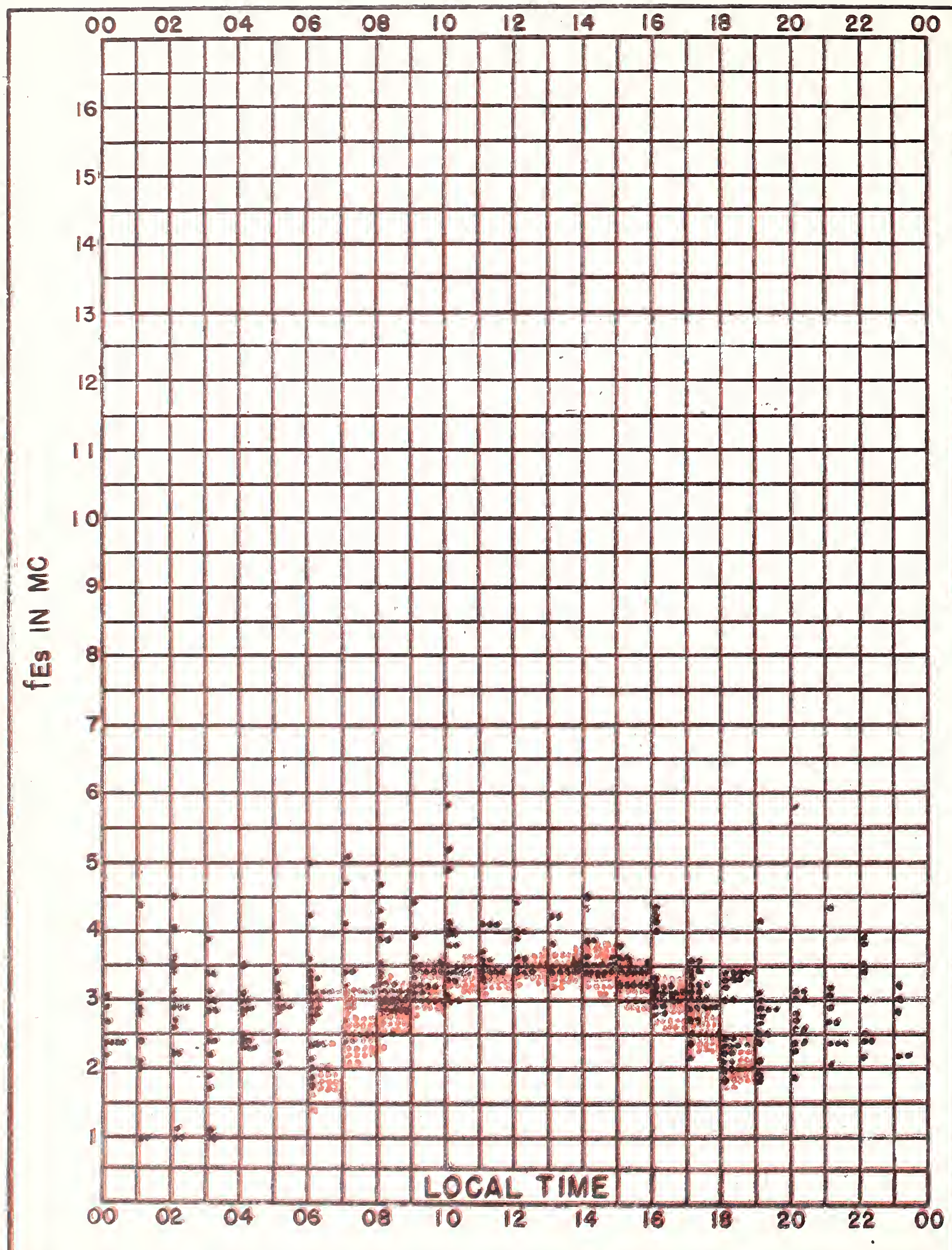

Fig. 24. WASHINGTON, D.C. APRIL, 1945

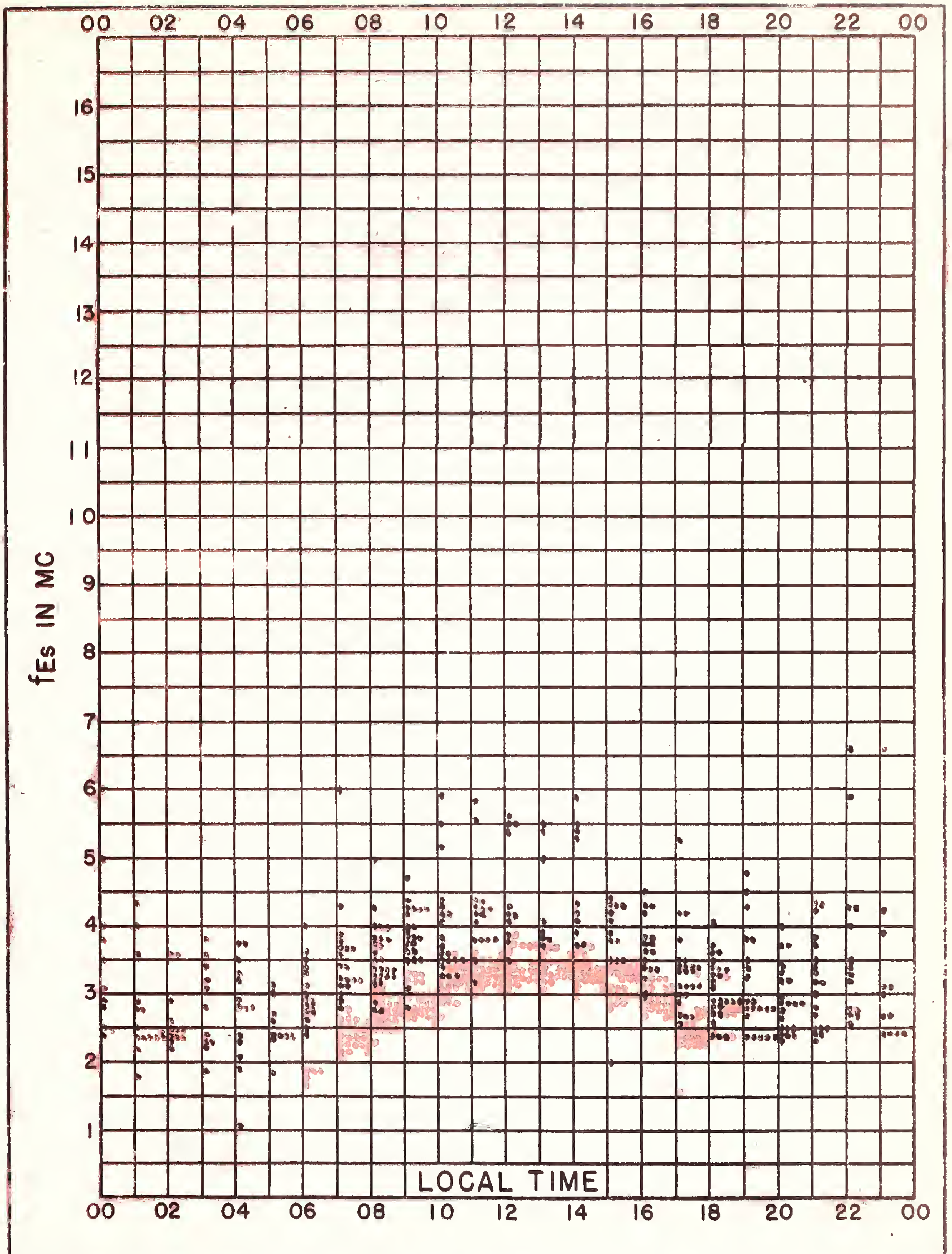

Fig.25. SAN FRANCISCO, CALIFORNIA • fEs ◦ f^oE APRIL, 1945

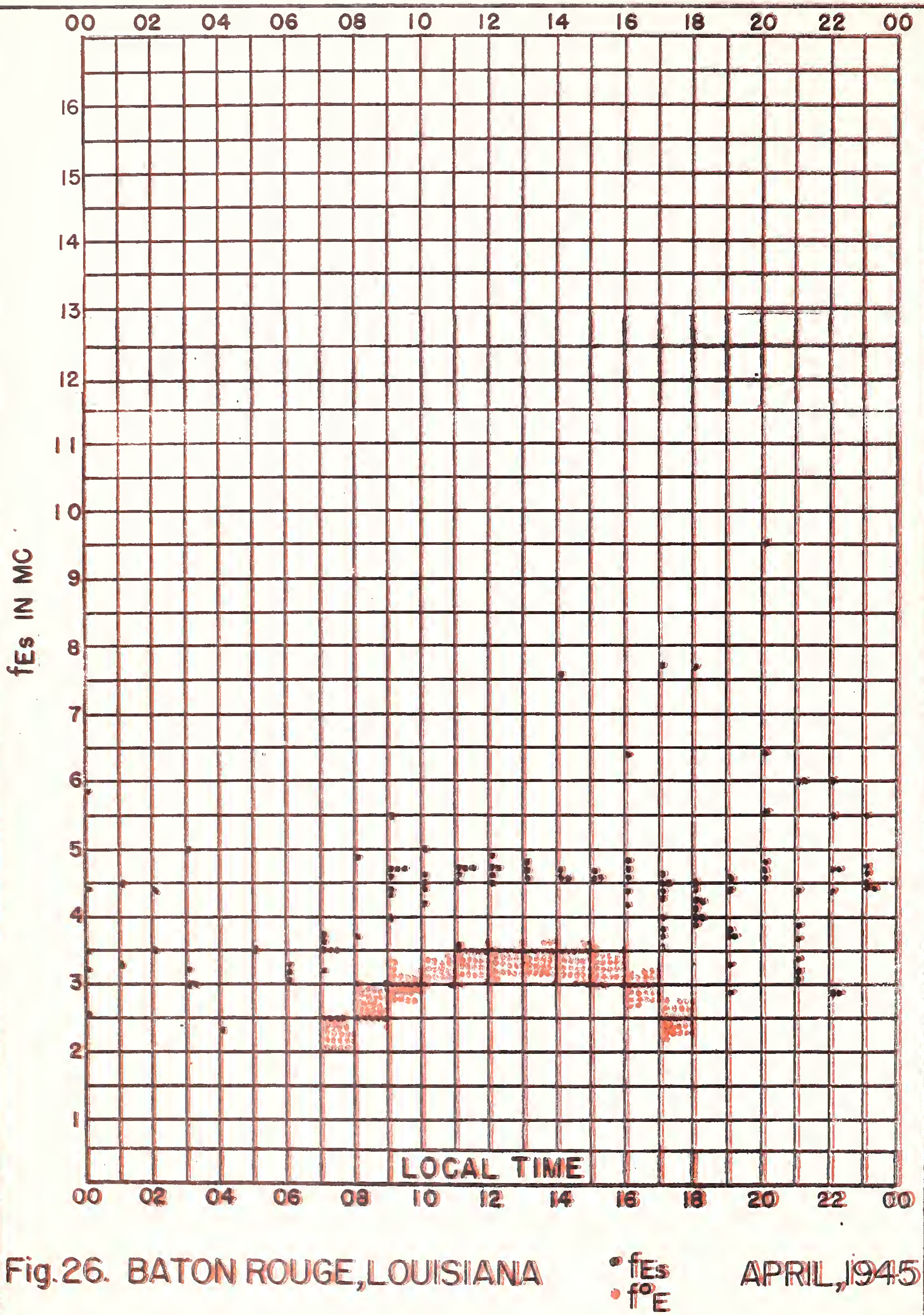

Fig. 26. BATON ROUGE, LOUISIANA — APRIL, 1945

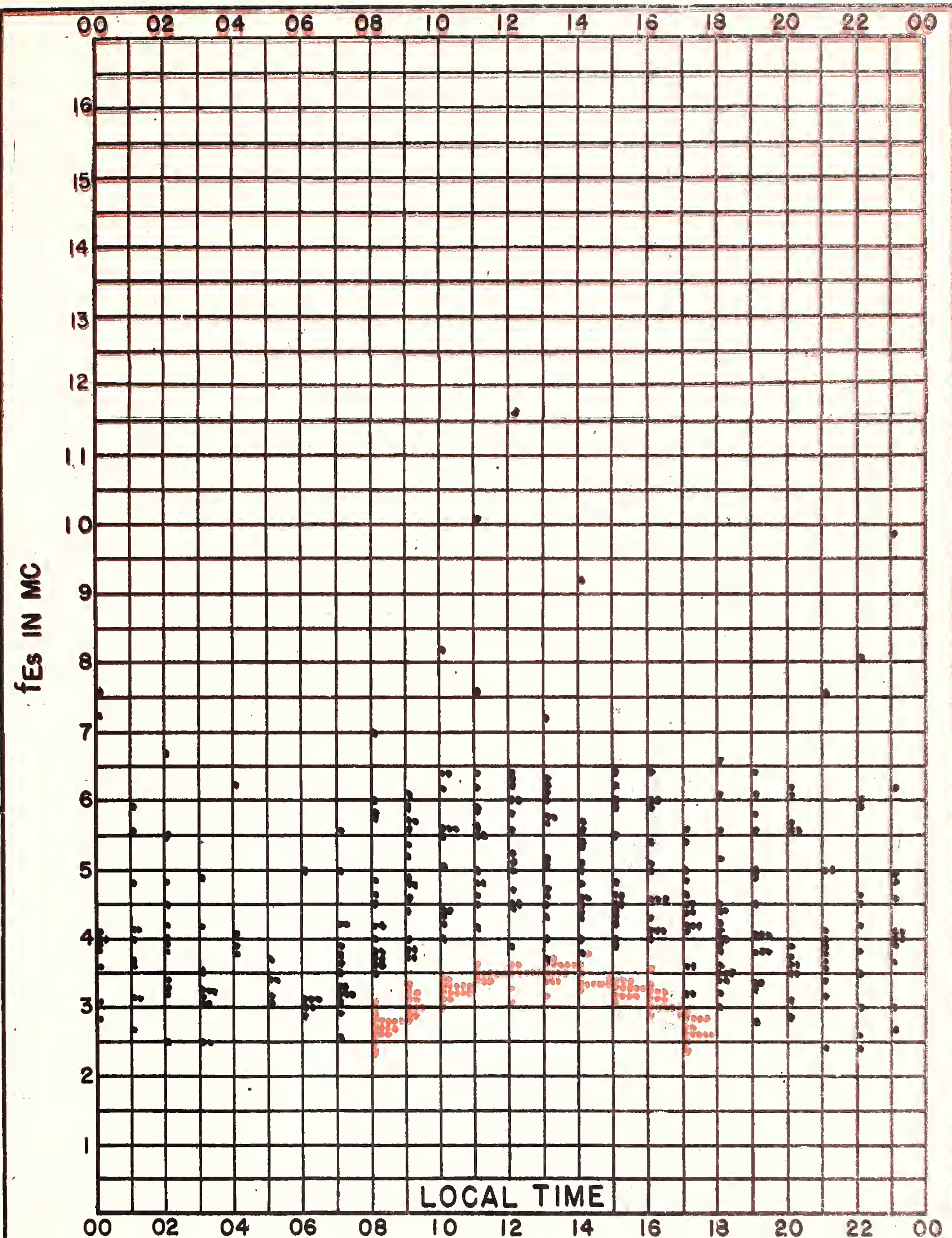

Fig. 27. MAUI, HAWAII • f_{Es} • f^oE APRIL, 1945

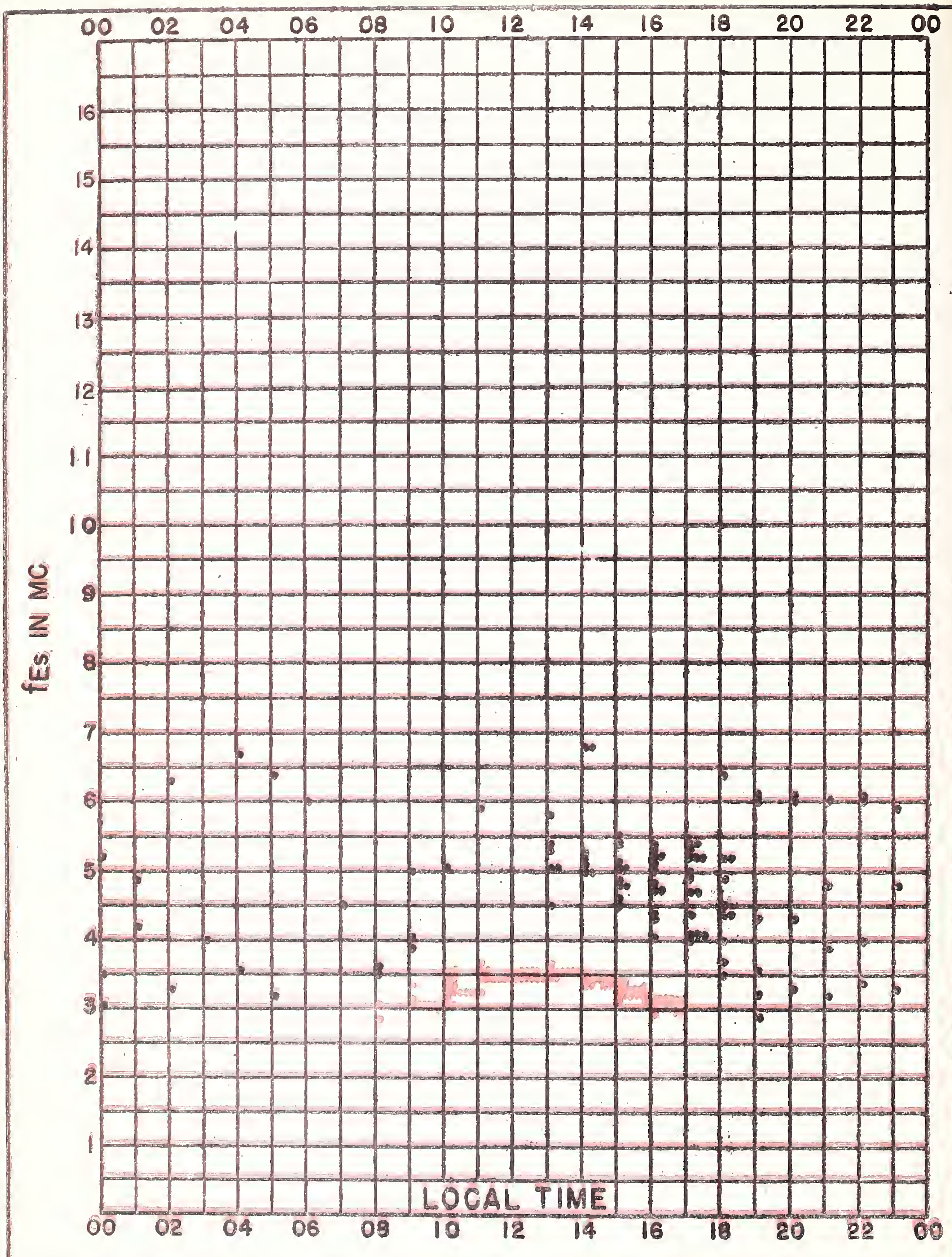

Fig.28. SAN JUAN, PUERTO RICO APRIL, 1945

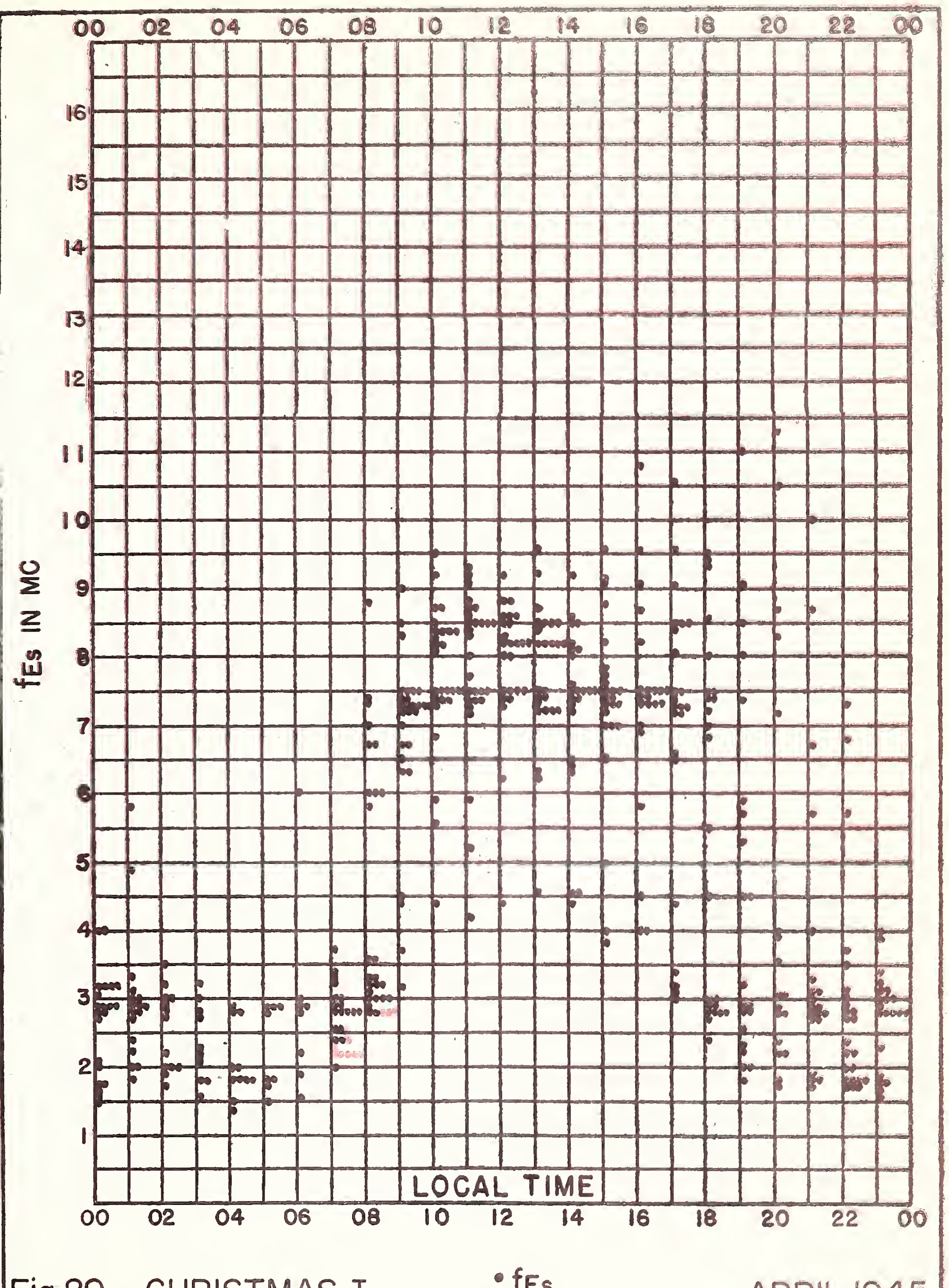

Fig. 29. CHRISTMAS I. APRIL, 1945

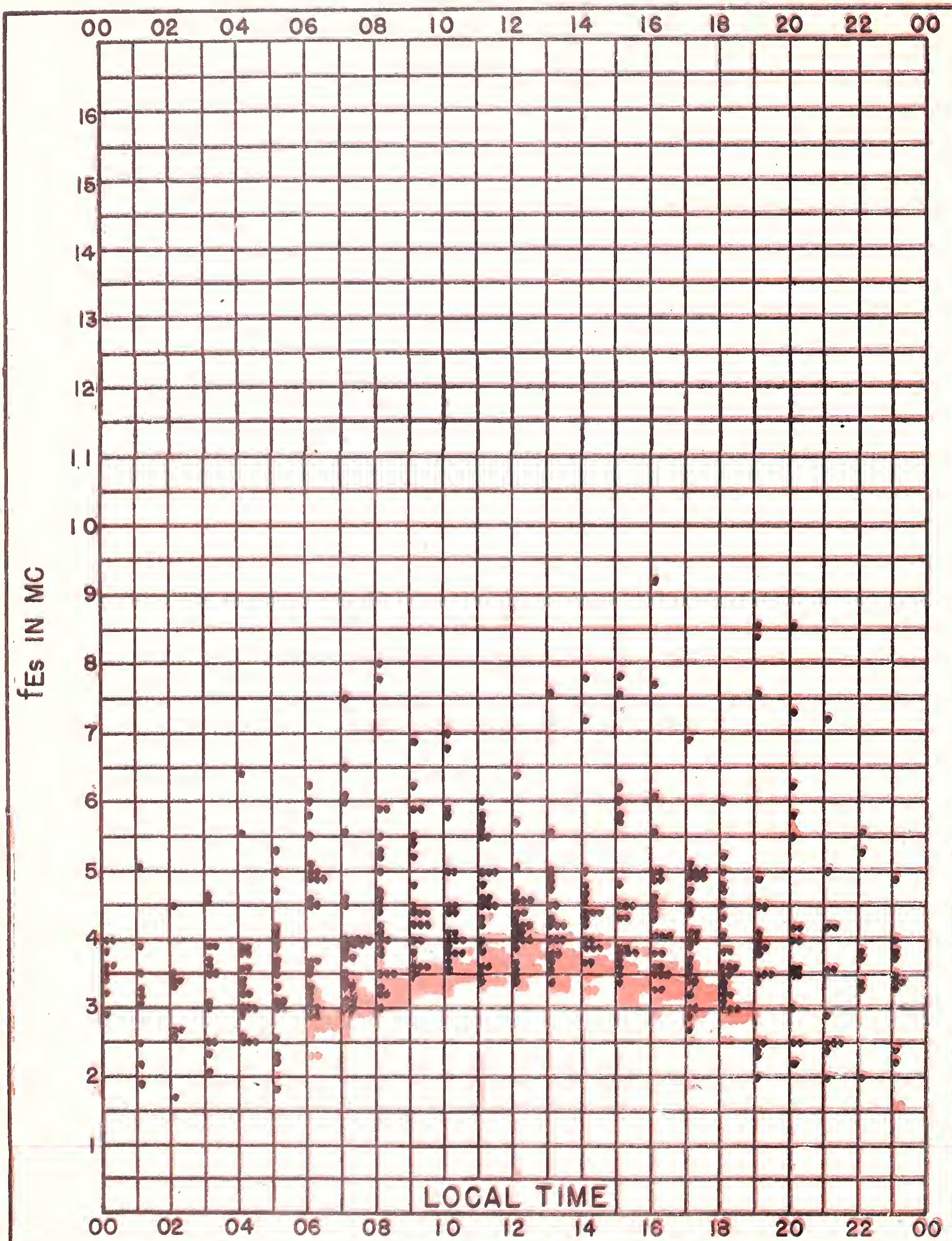

Fig. 30. HOLLANDIA, NEW GUINEA APRIL, 1945

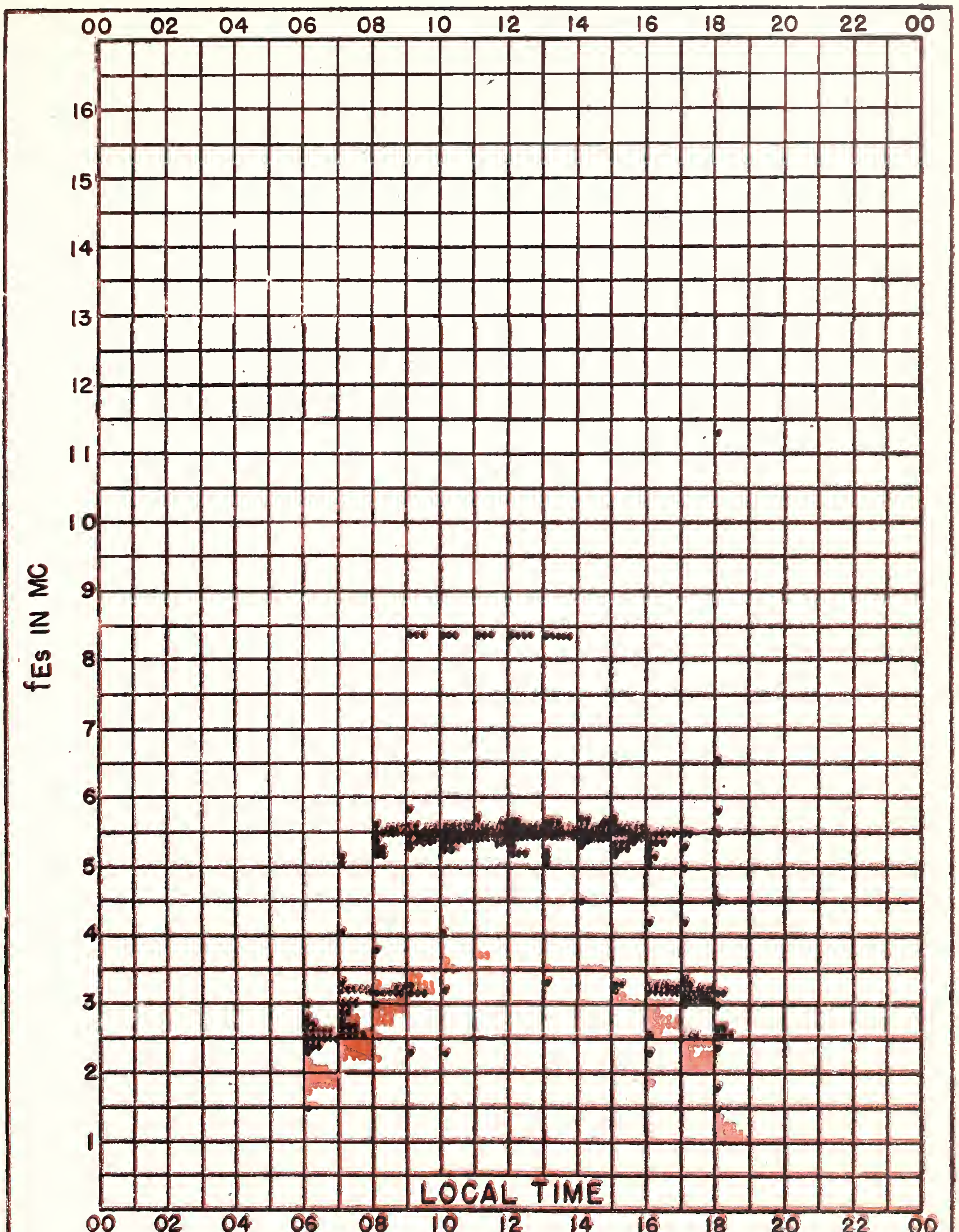

Fig.31. HUANCAYO, PERU • fEs • foE APRIL, 1945

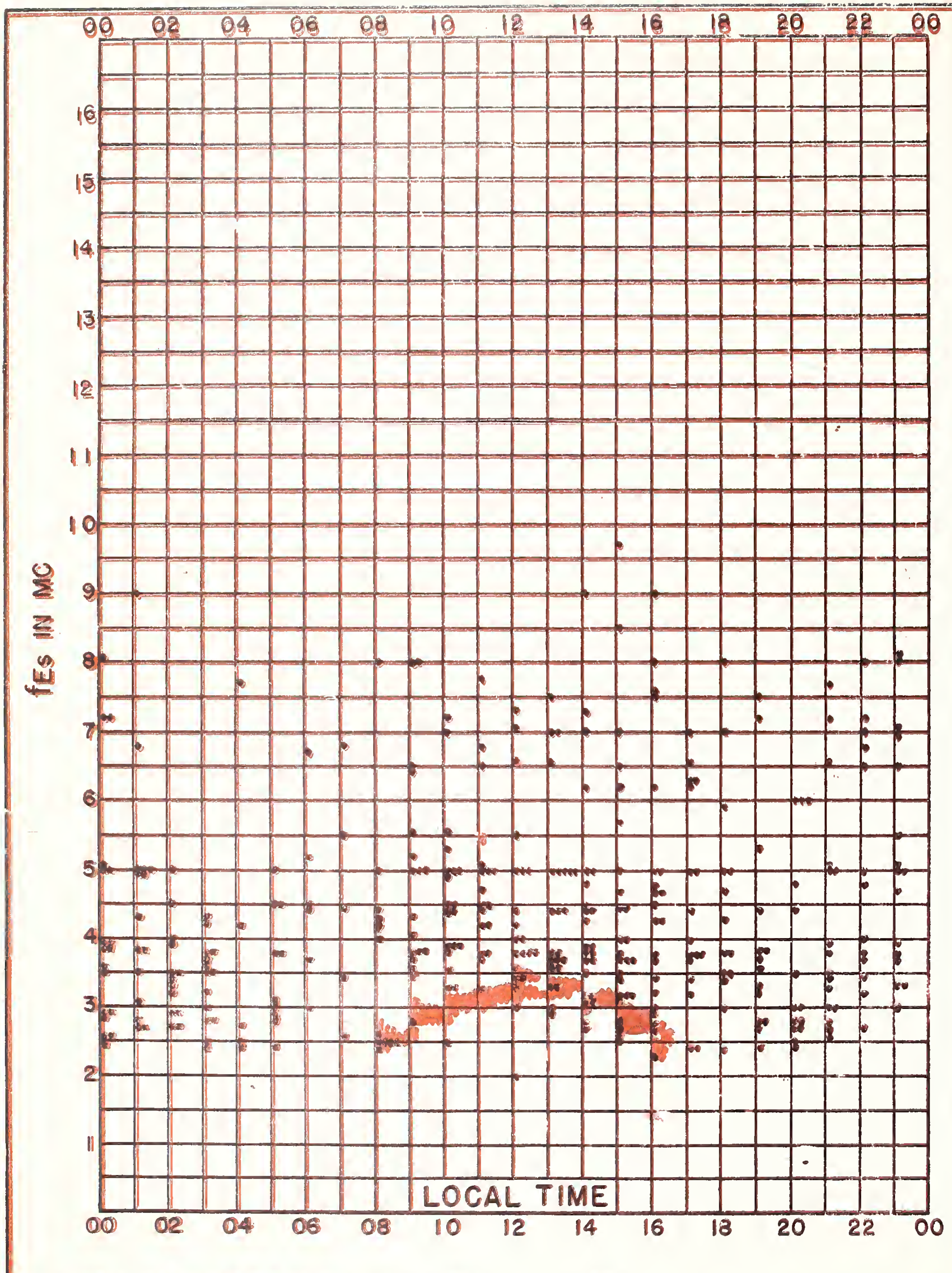

Fig. 32. BRISBANE, AUSTRALIA • fEs • f°E APRIL, 1945

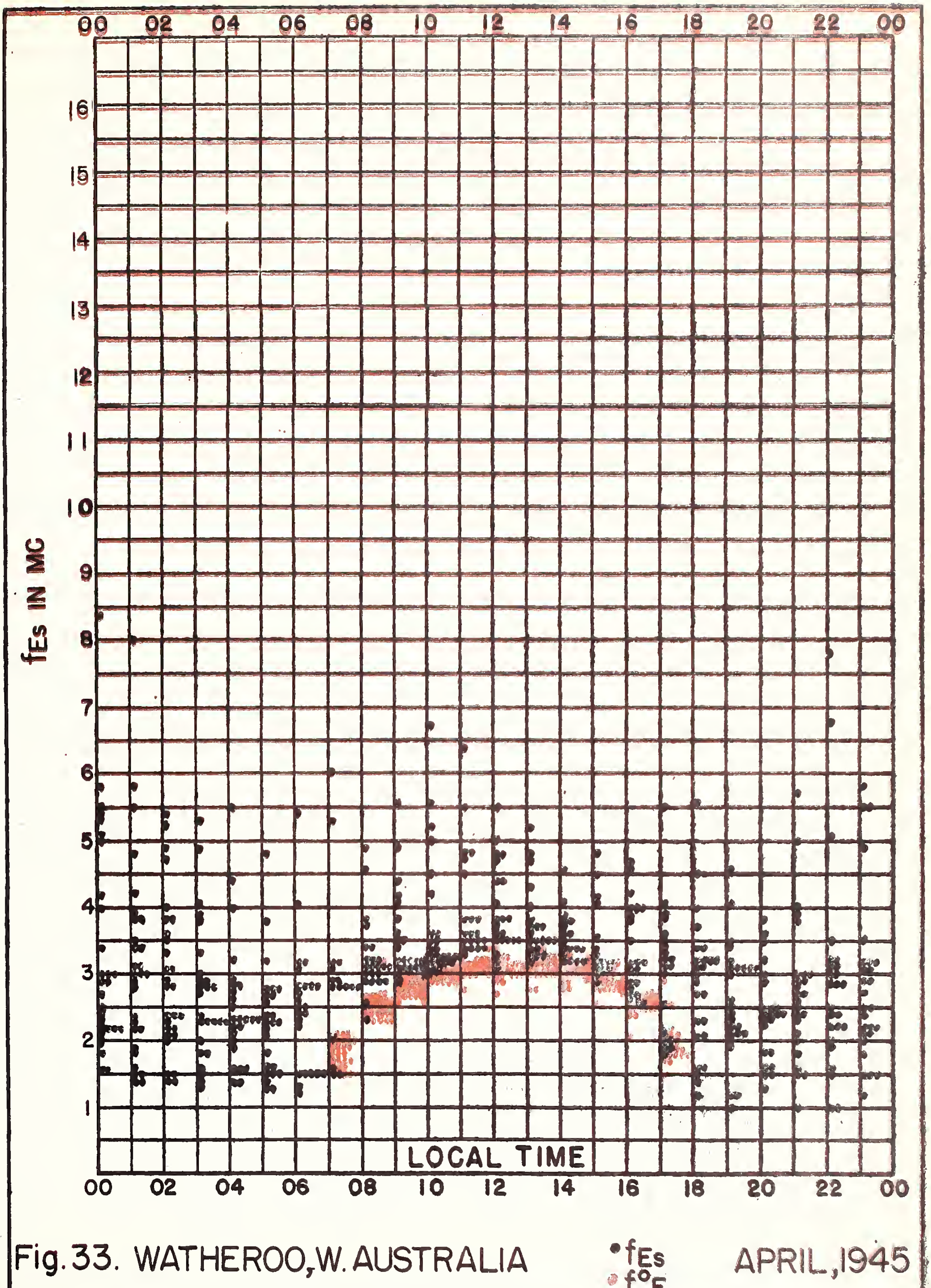

Fig. 33. WATHEROO, W. AUSTRALIA APRIL, 1945

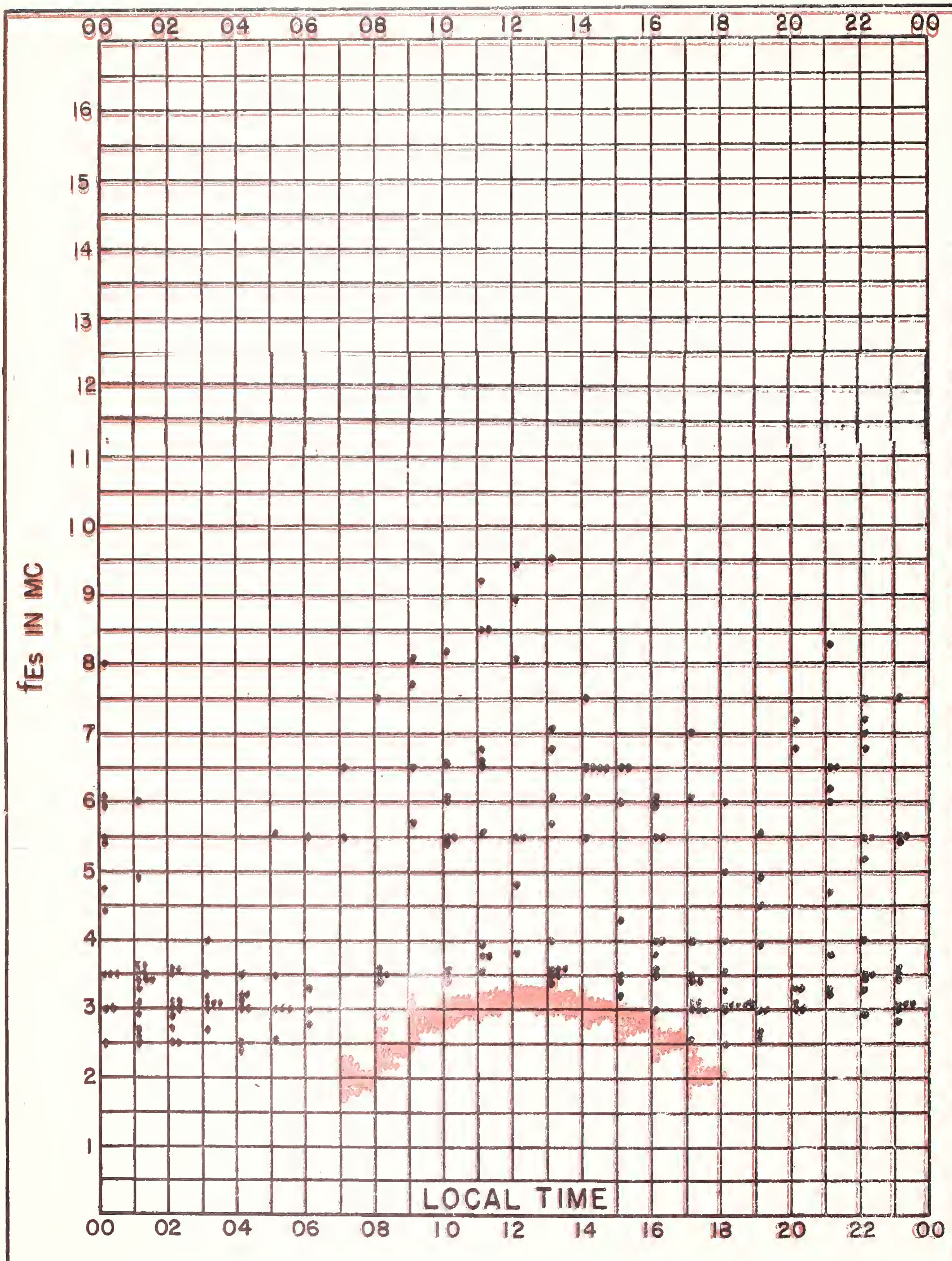

Fig. 34. CANBERRA, AUSTRALIA APRIL, 1945

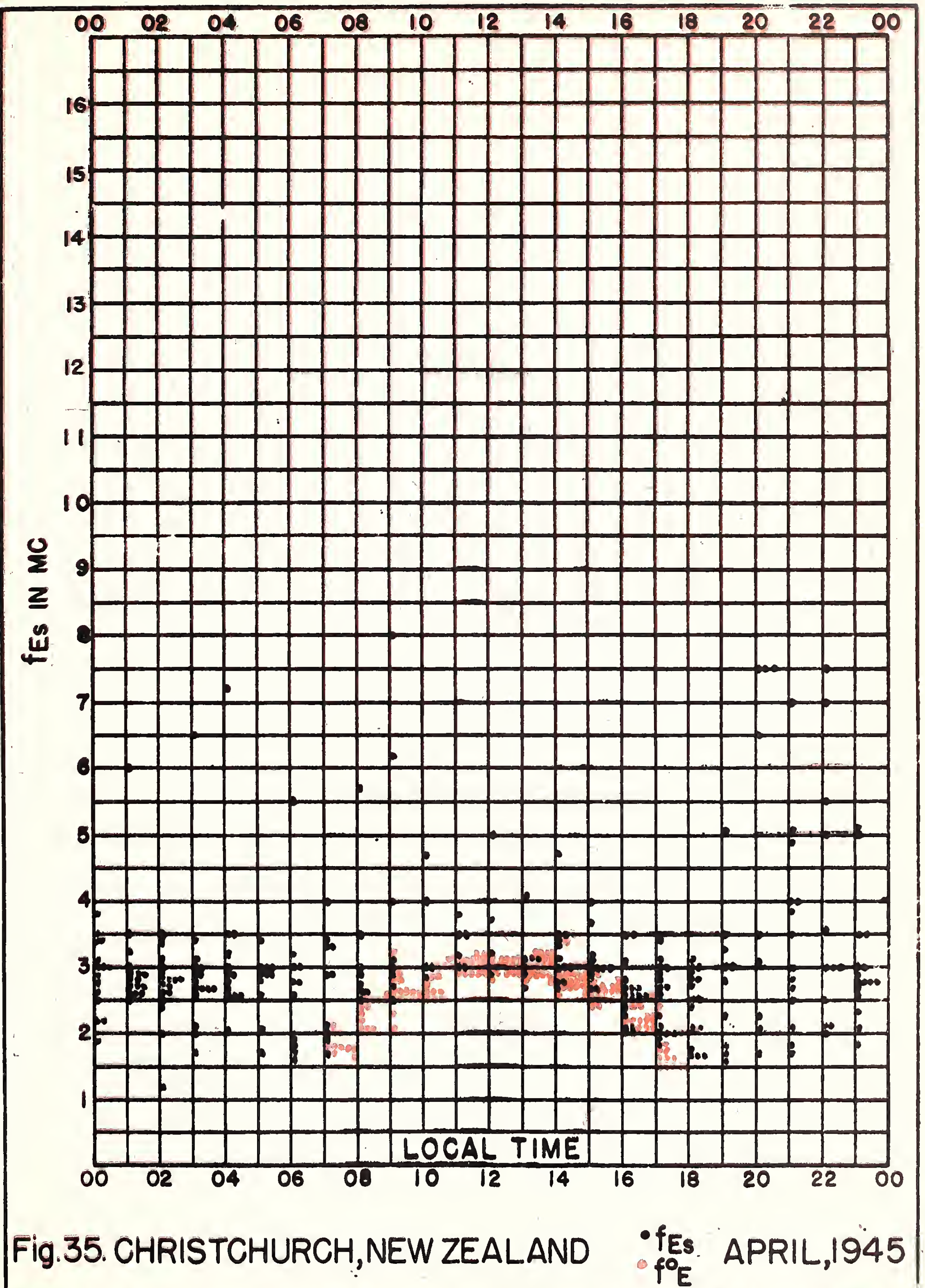

Fig.35. CHRISTCHURCH, NEW ZEALAND APRIL, 1945

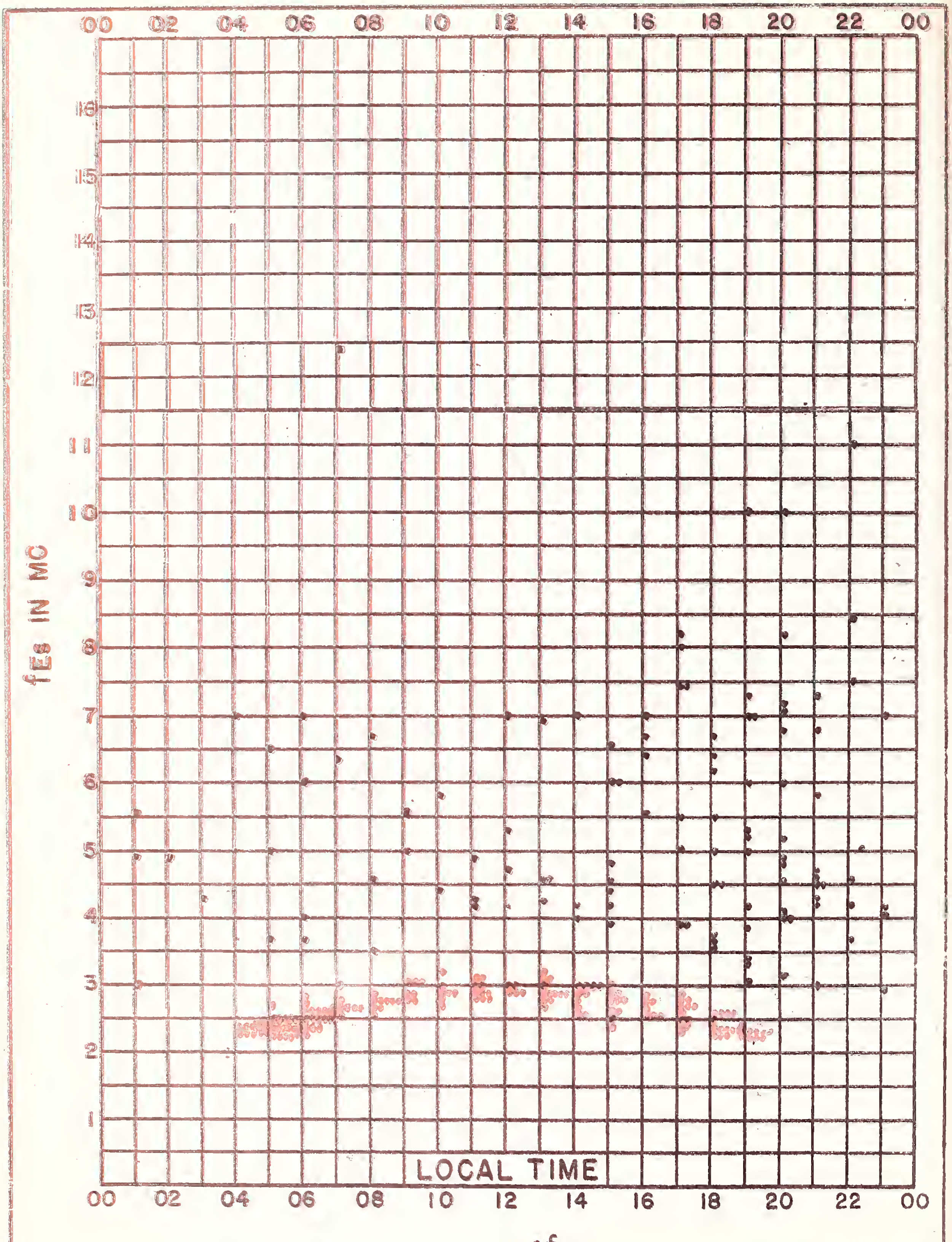

Fig. 36. CLYDE, BAFFIN I. JUNE, 1945

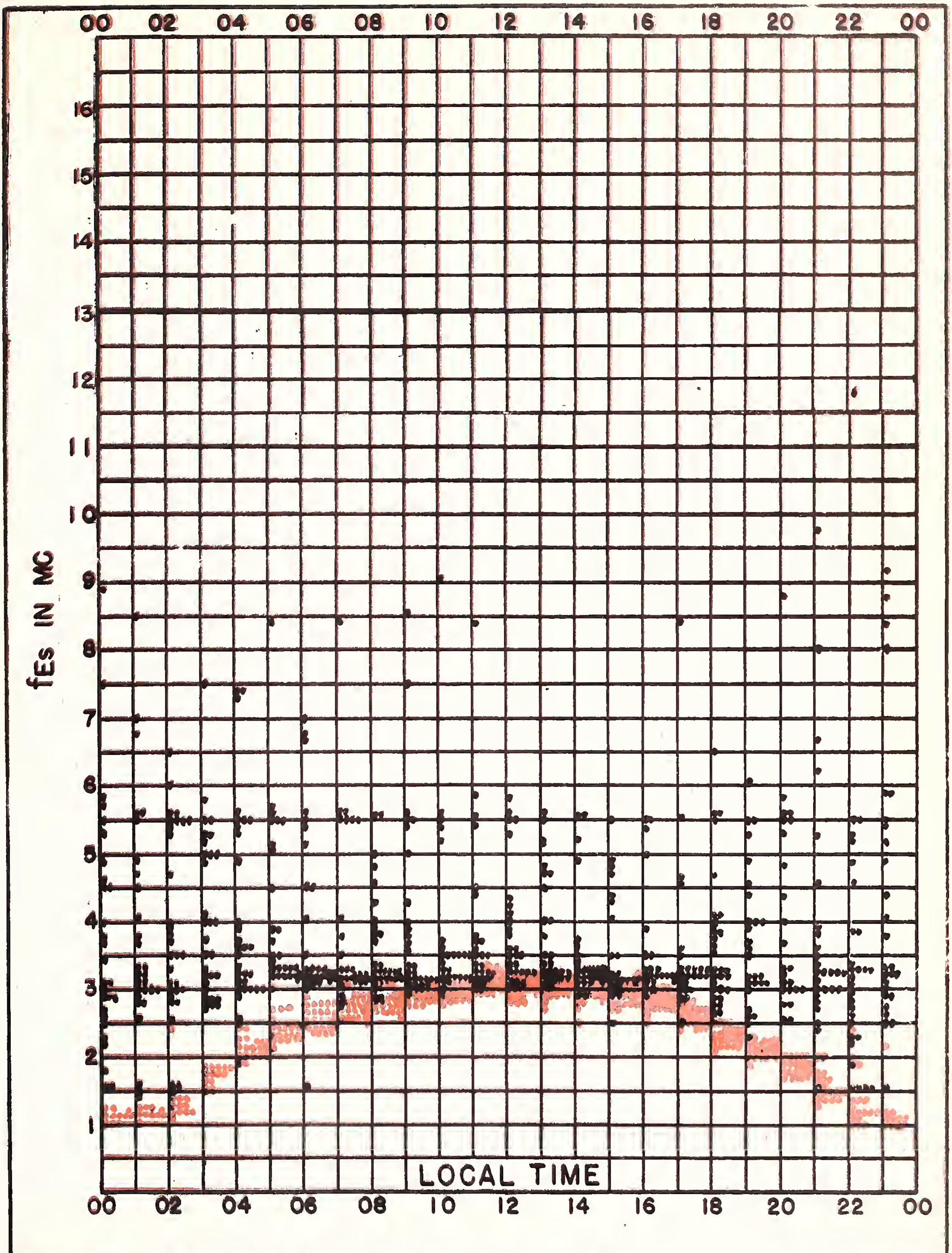

Fig. 37. COLLEGE, ALASKA JUNE, 1945

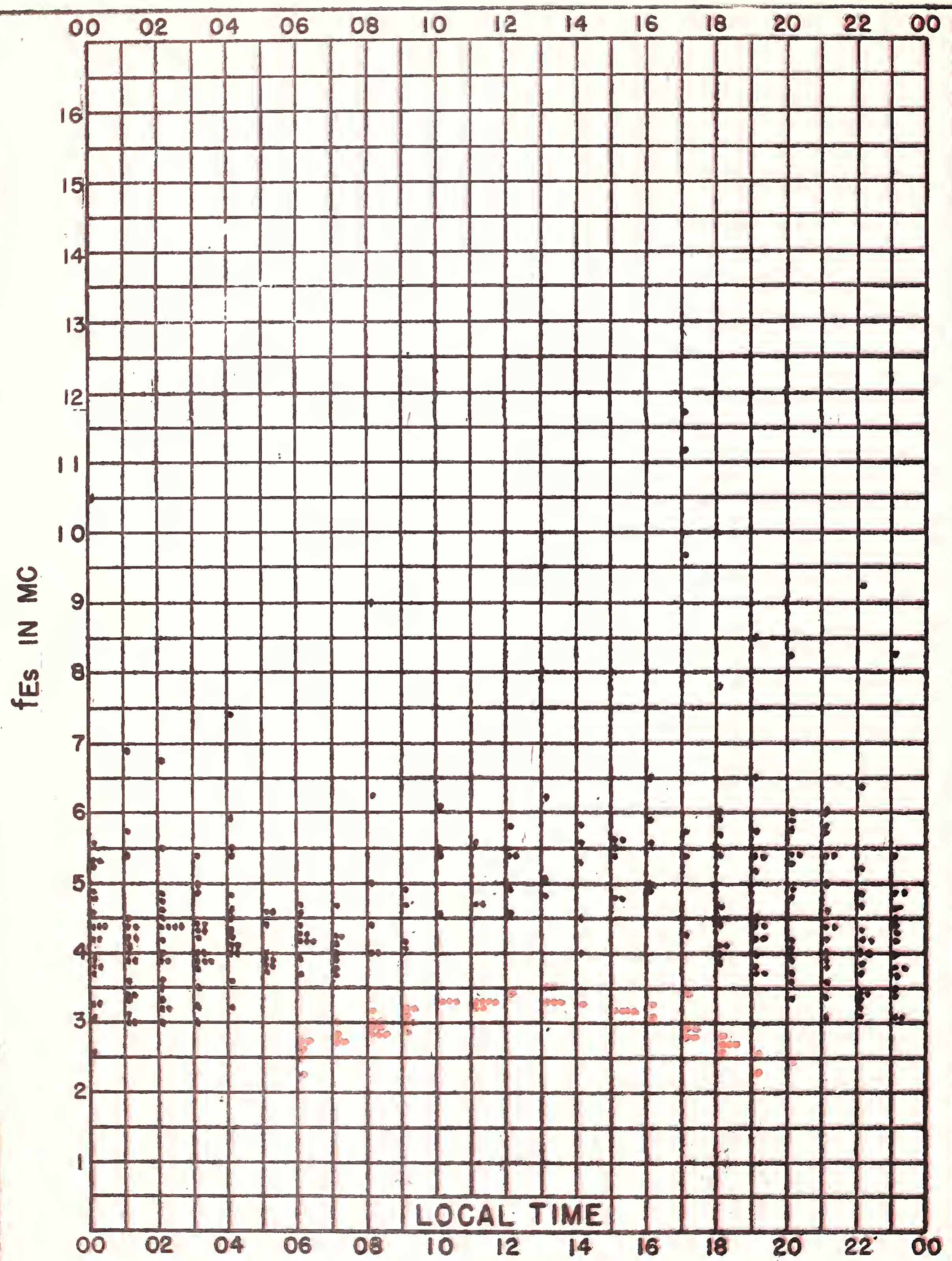

Fig. 38. REYKJAVIK, ICELAND • f_{Es} • f^{o}_{E} JUNE, 1945

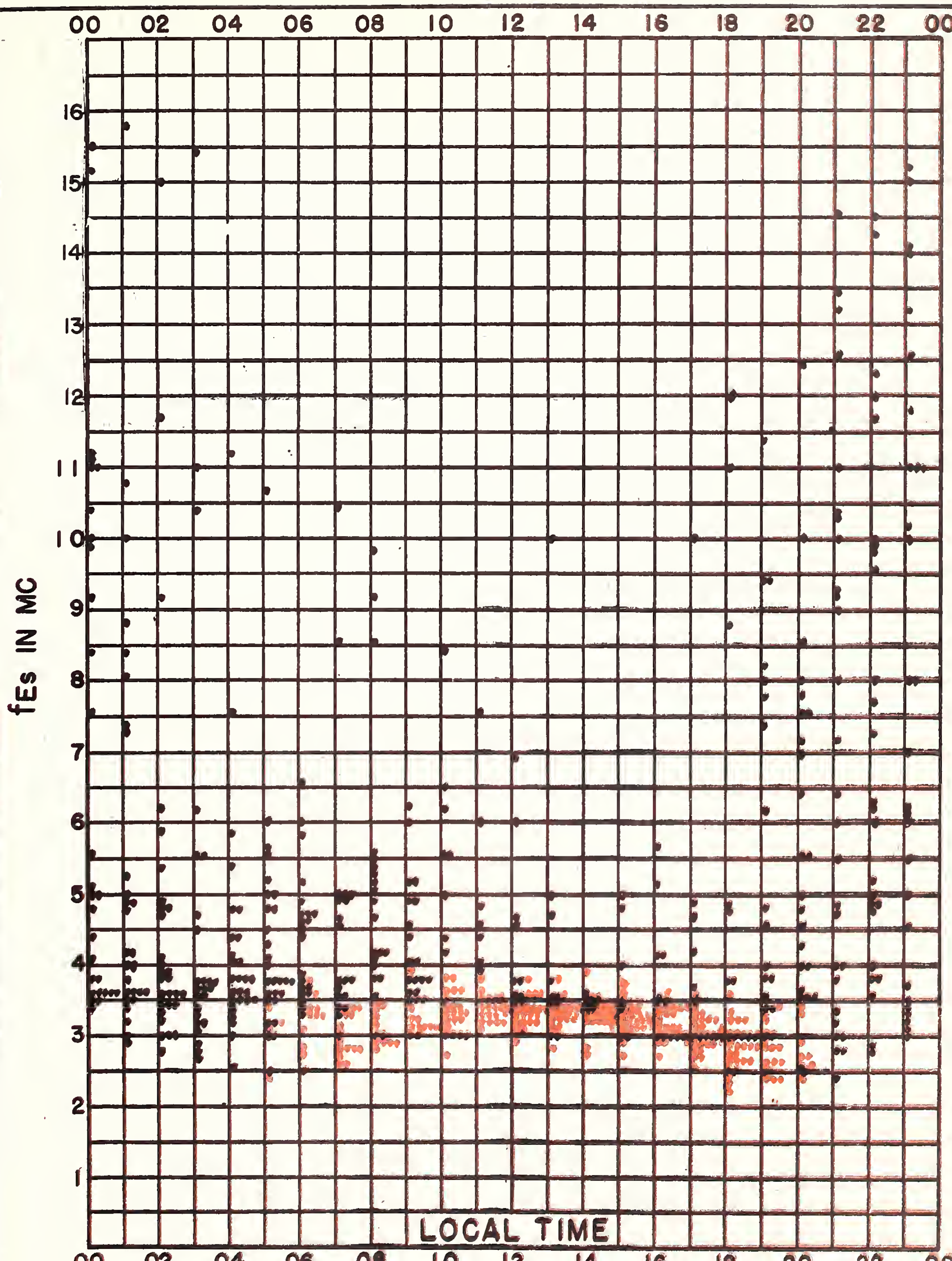

Fig. 39. CHURCHILL, CANADA JUNE, 1945

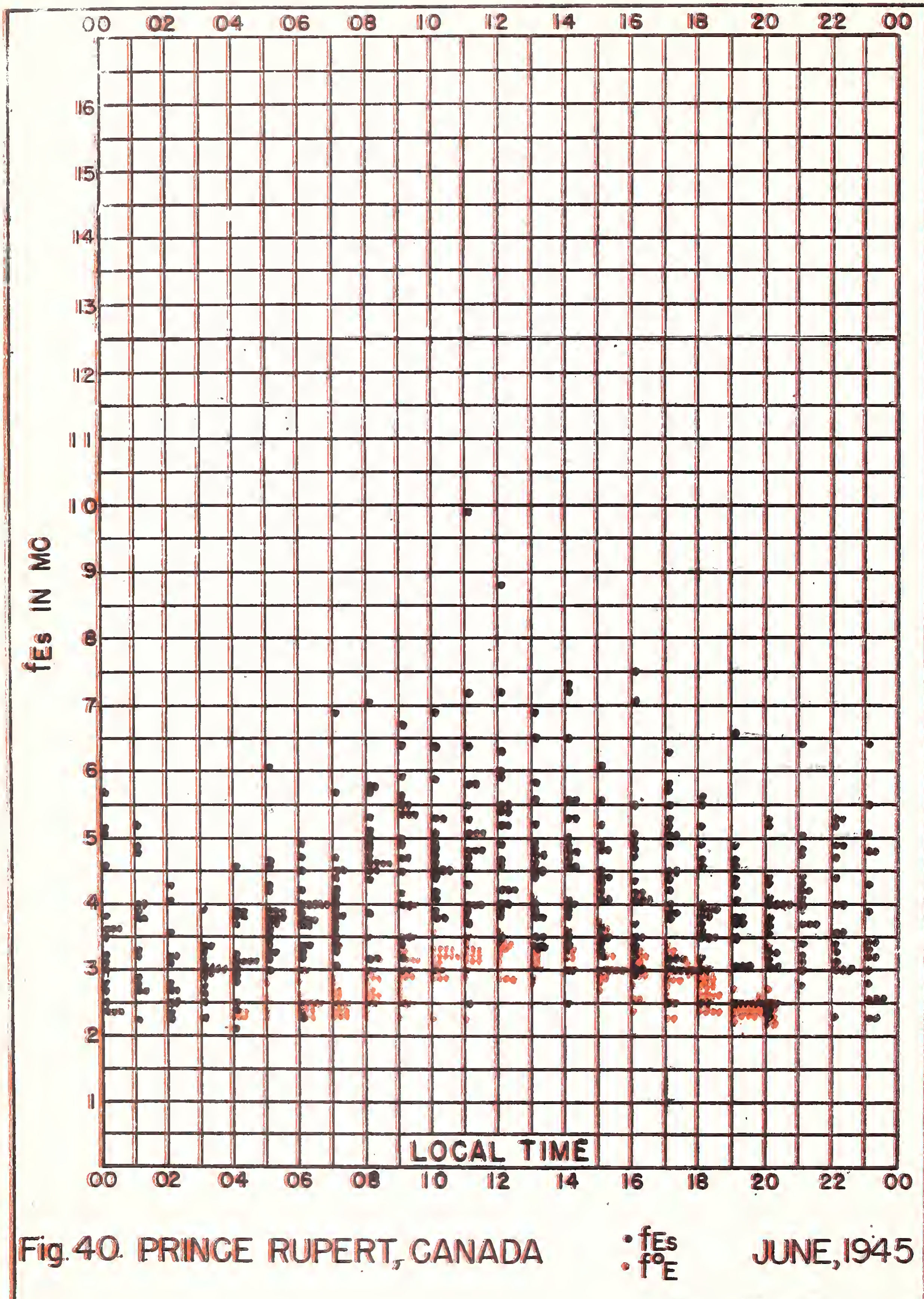

Fig. 40. PRINCE RUPERT, CANADA JUNE, 1945

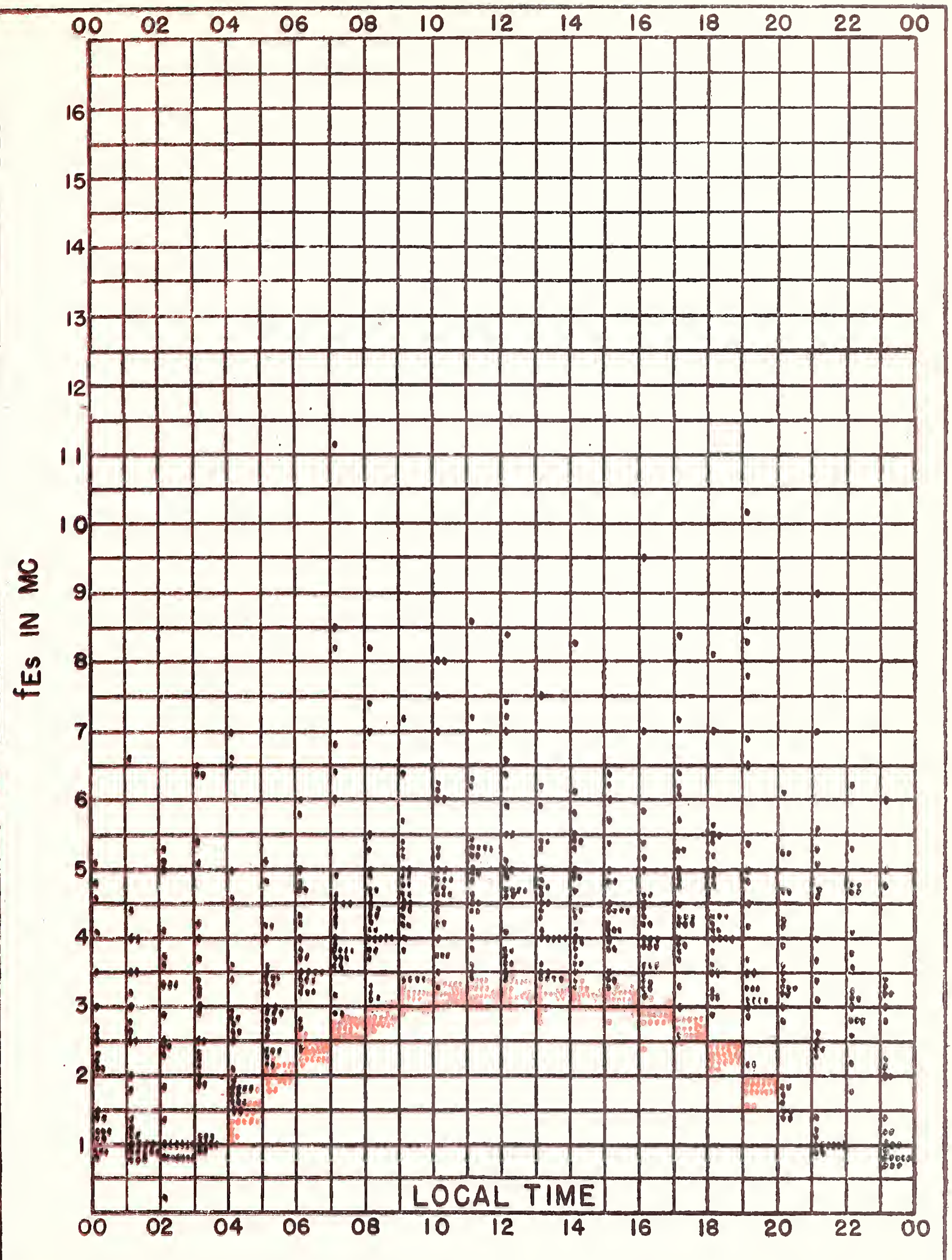

Fig.41. GREAT BADDOW, ENGLAND JUNE, 1945

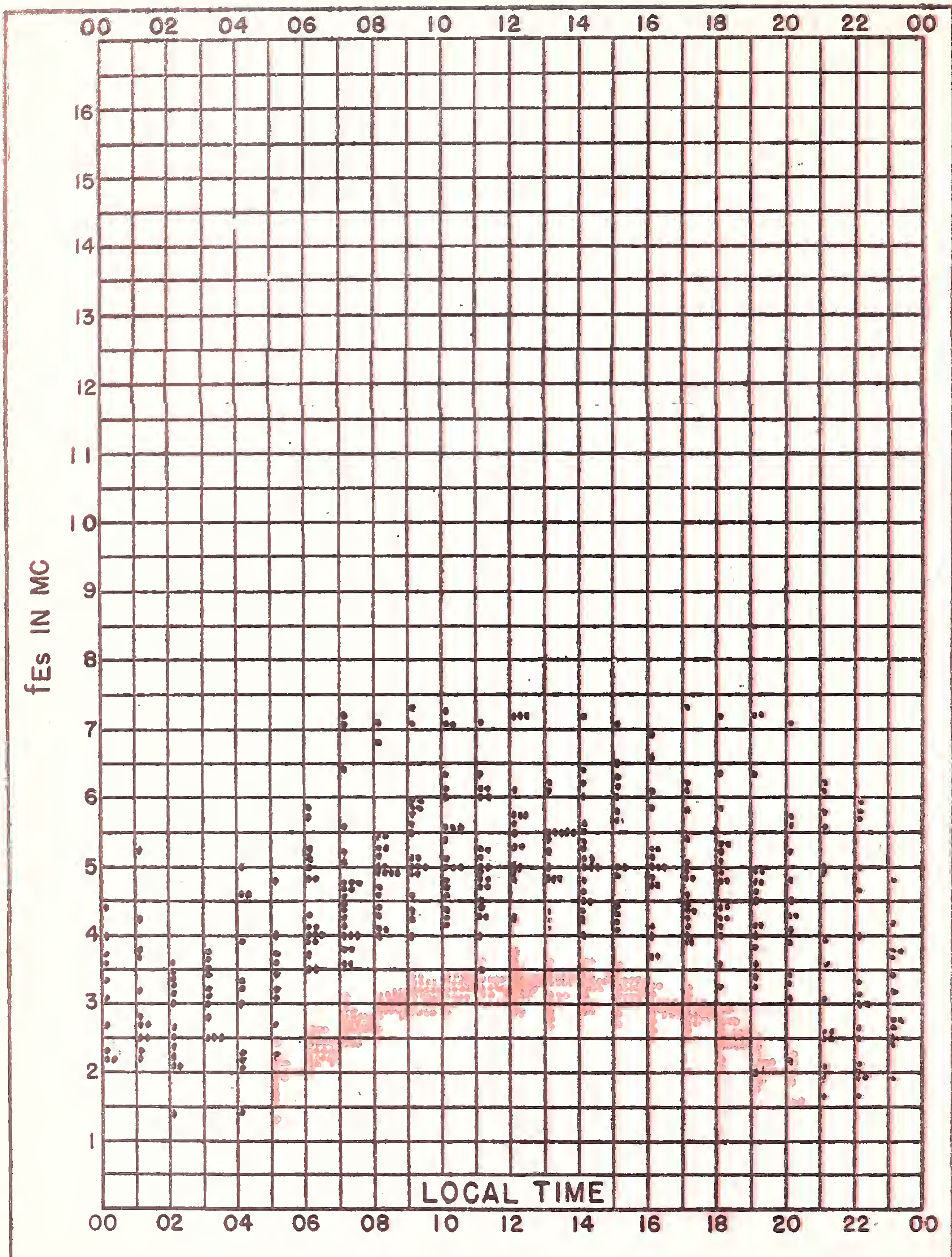

Fig.42. ST.JOHN'S, NEWFOUNDLAND JUNE, 1945

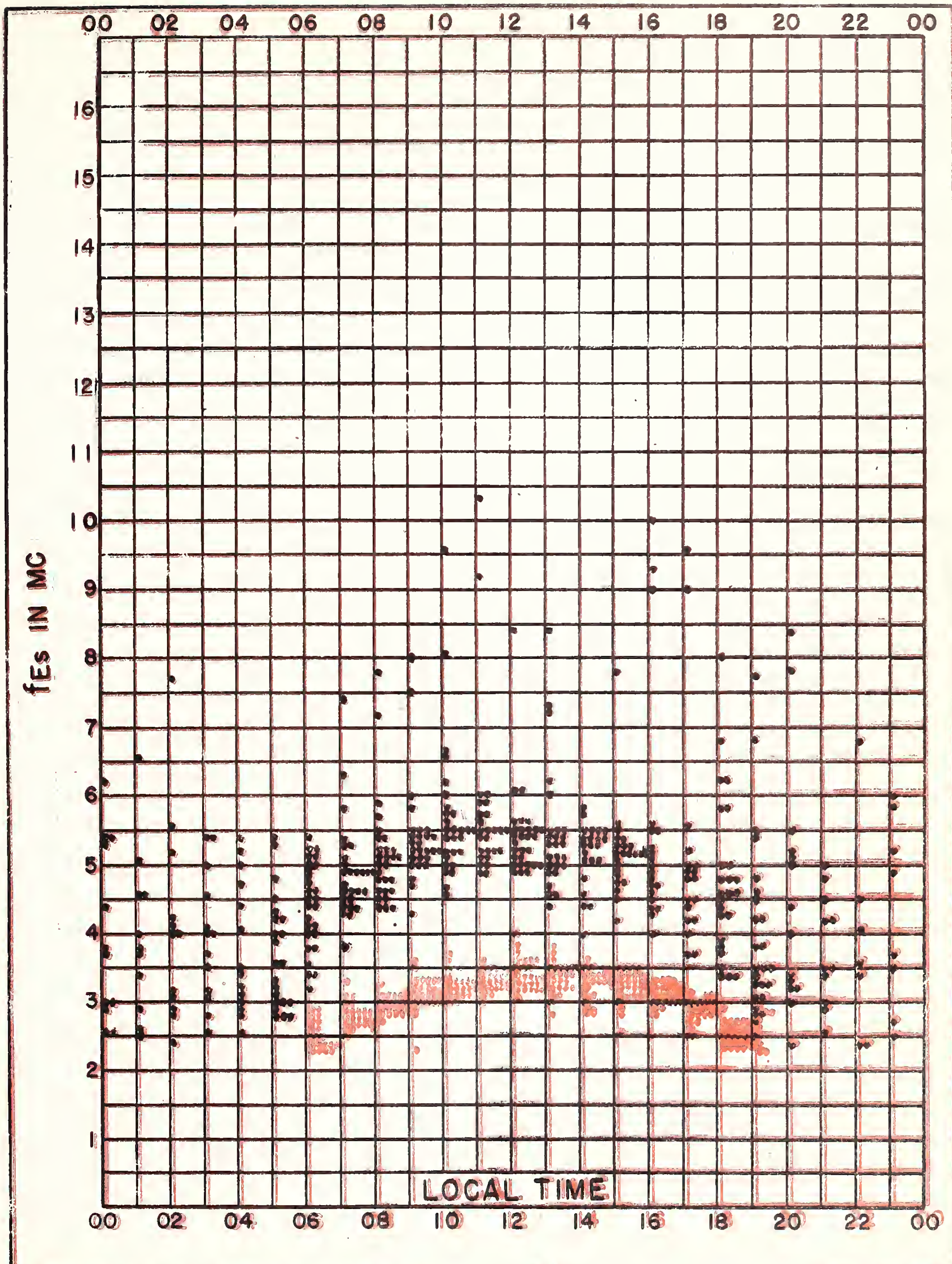

Fig. 43. OTTAWA, CANADA JUNE, 1945

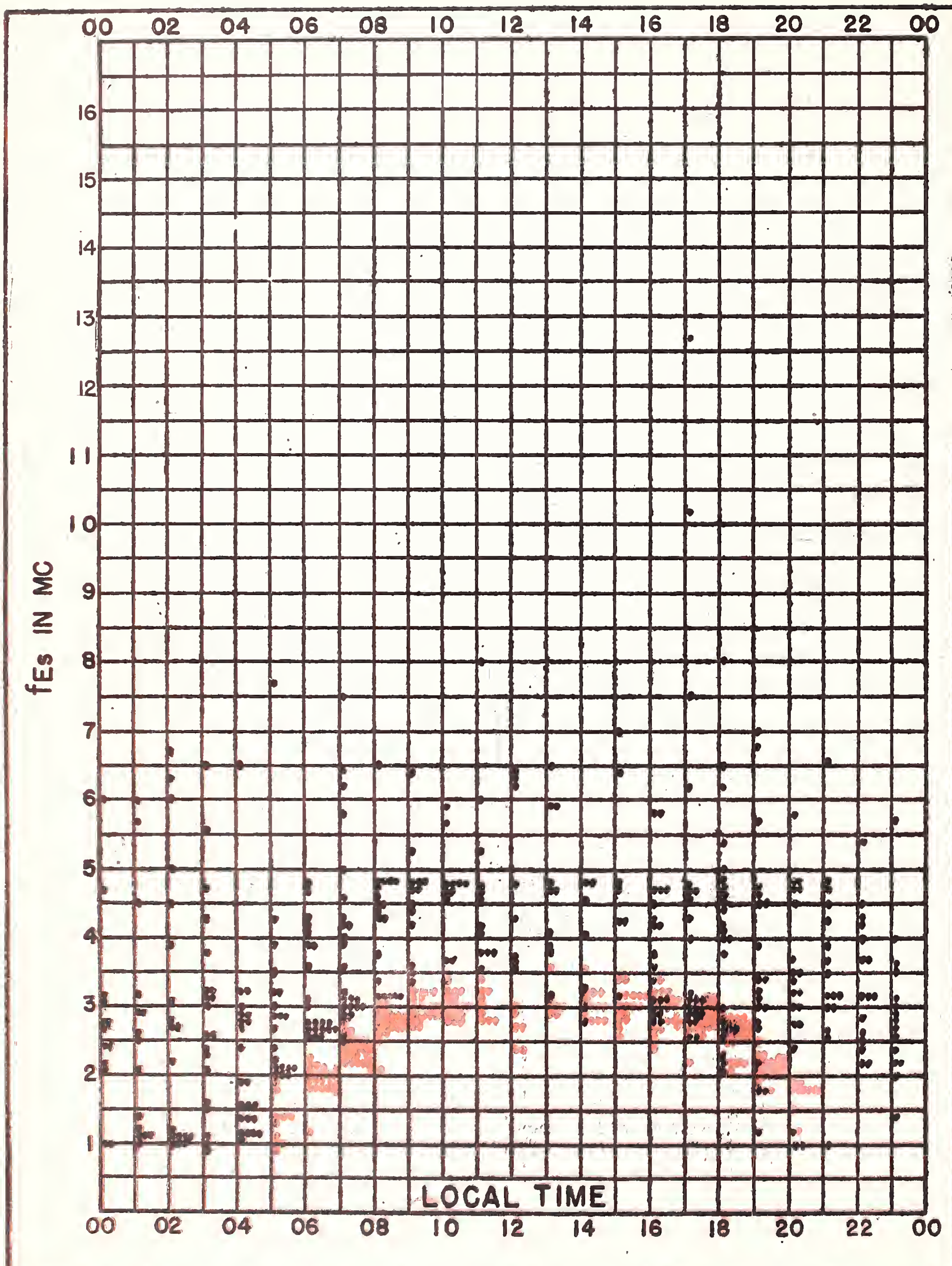

Fig.44. BOSTON, MASSACHUSETTS JUNE, 1945

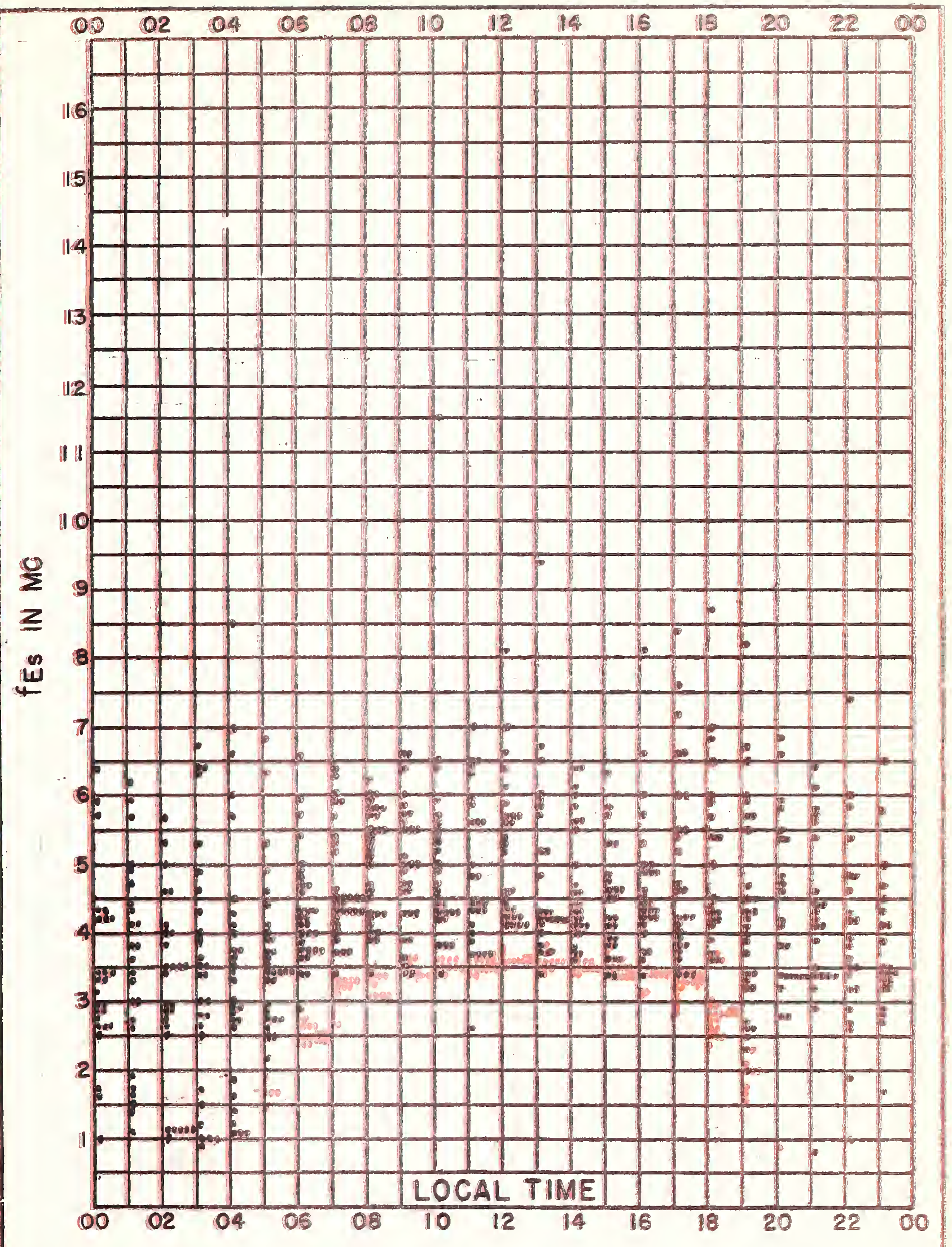

Fig.45. WASHINGTON, D.C. JUNE, 1945

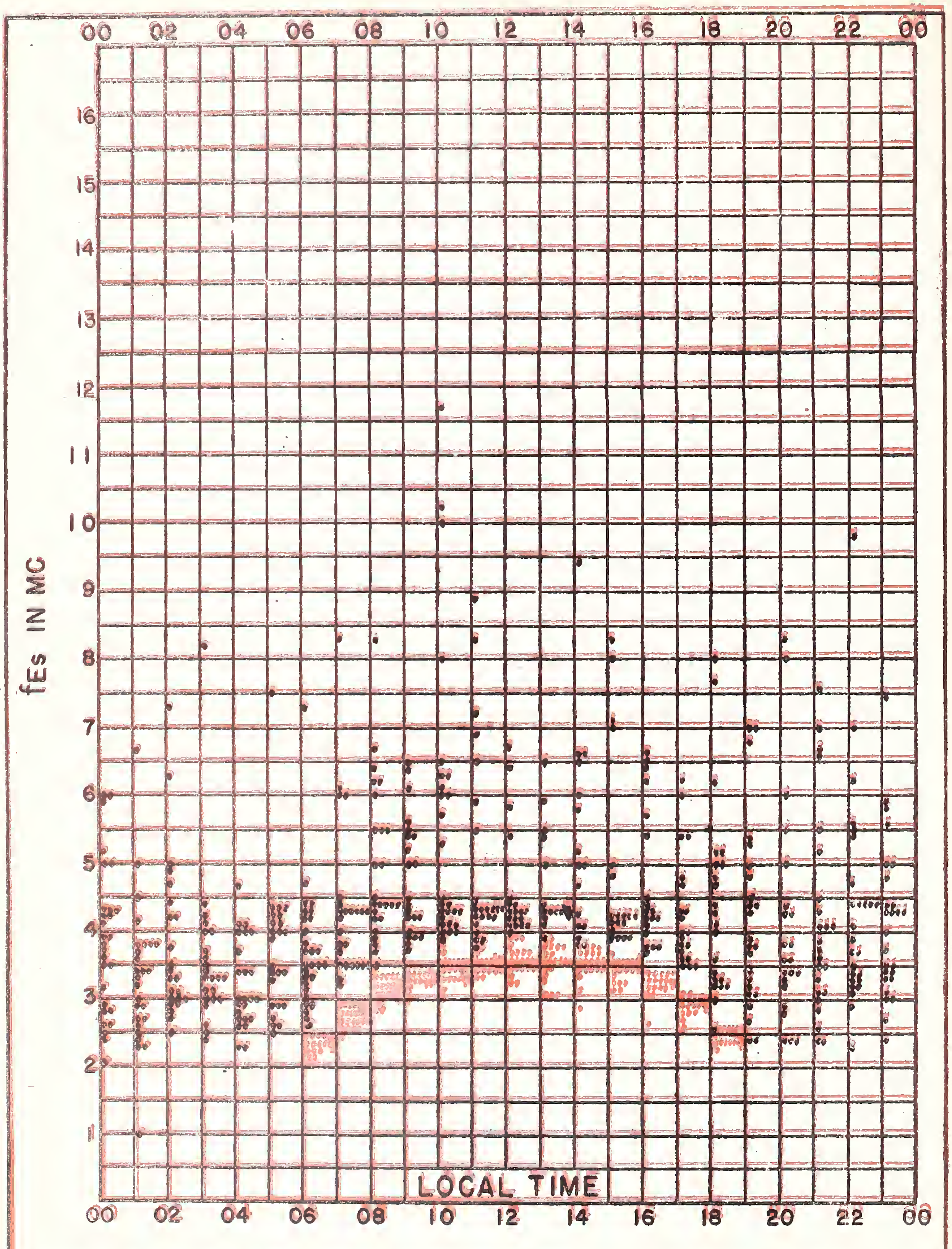

Fig.46 SAN FRANCISCO, CALIFORNIA JUNE, 1945

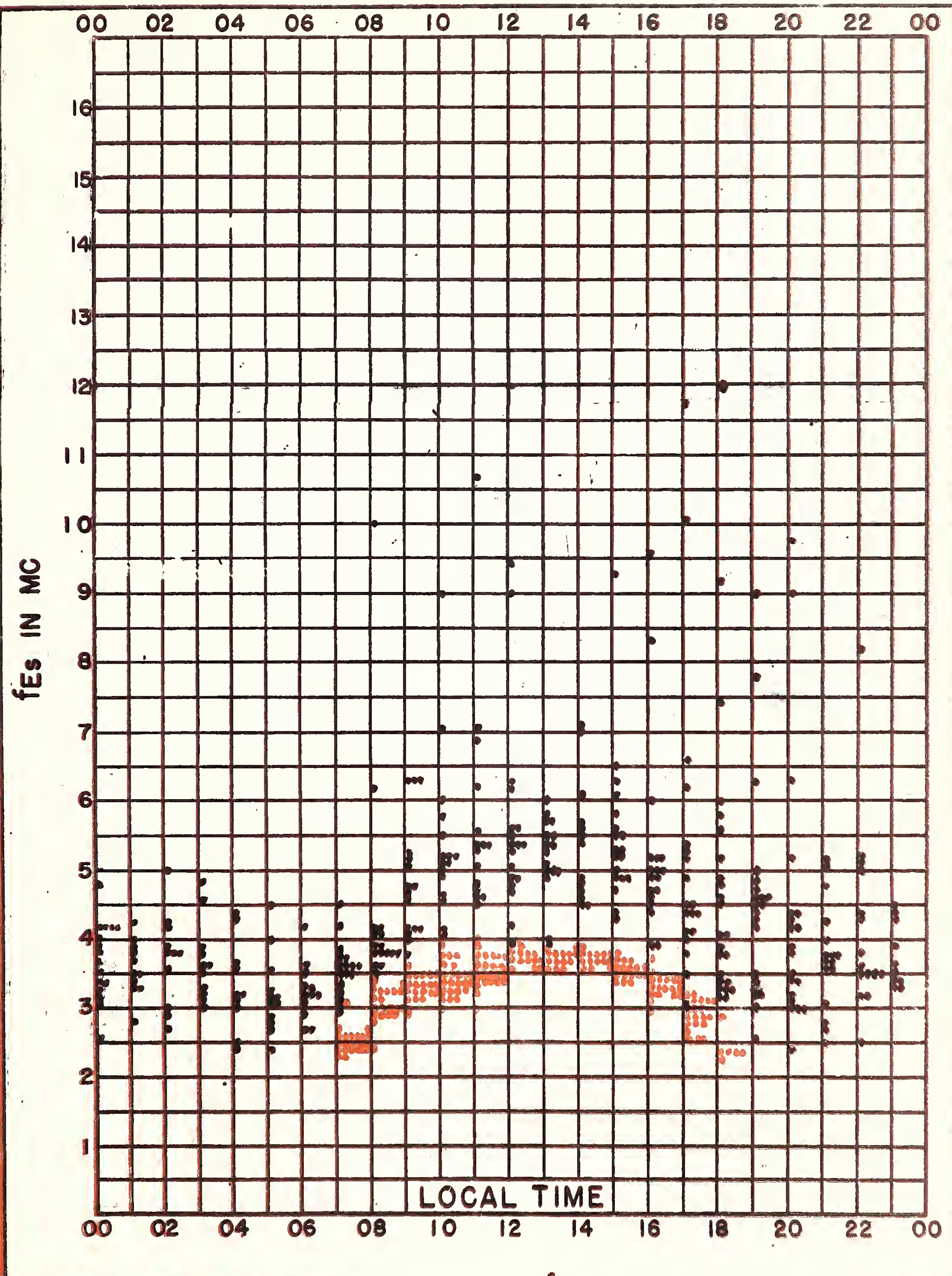

Fig. 47 MAUI, HAWAII JUNE, 1945

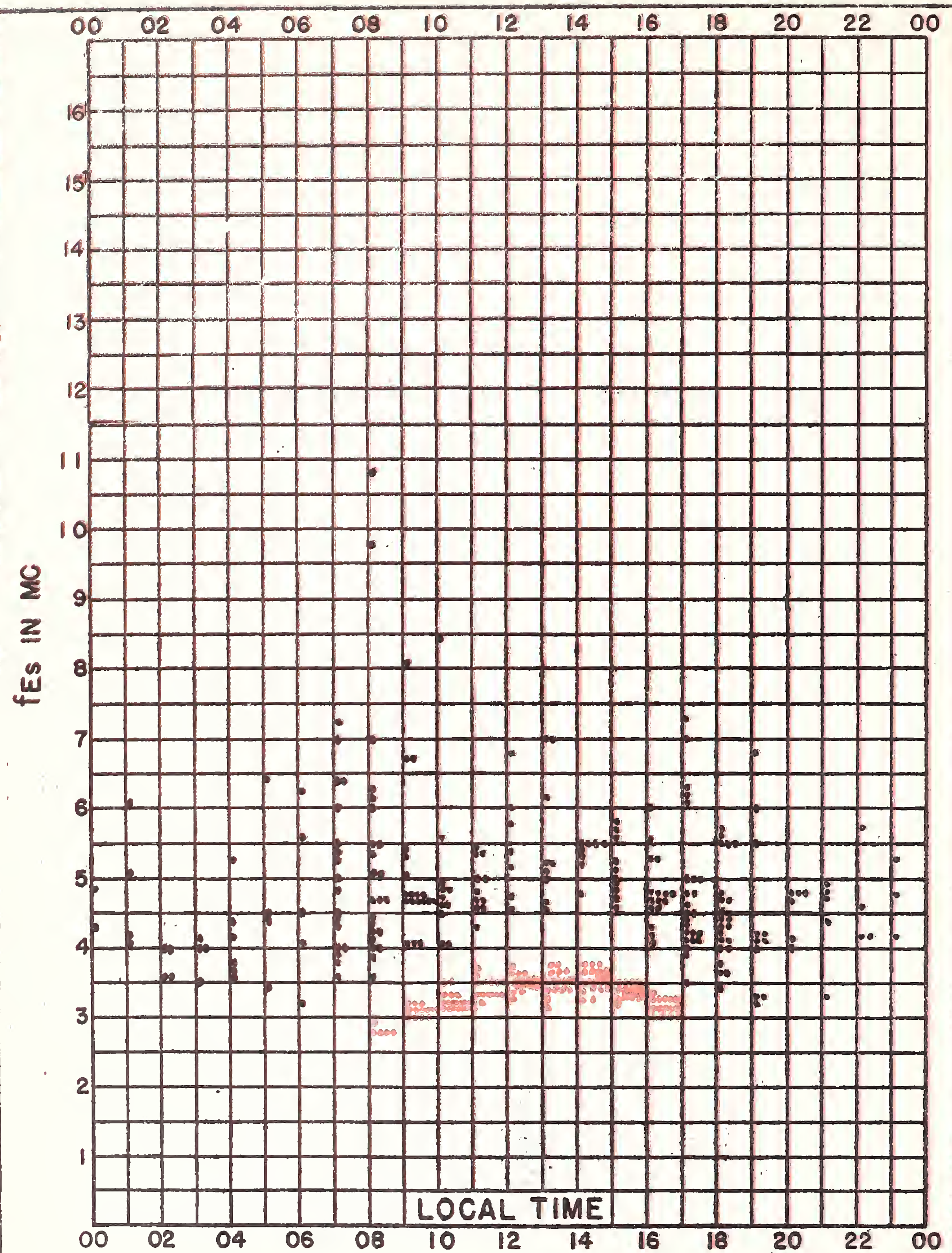

Fig.48. SAN JUAN, PUERTO.RICO JUNE,1945

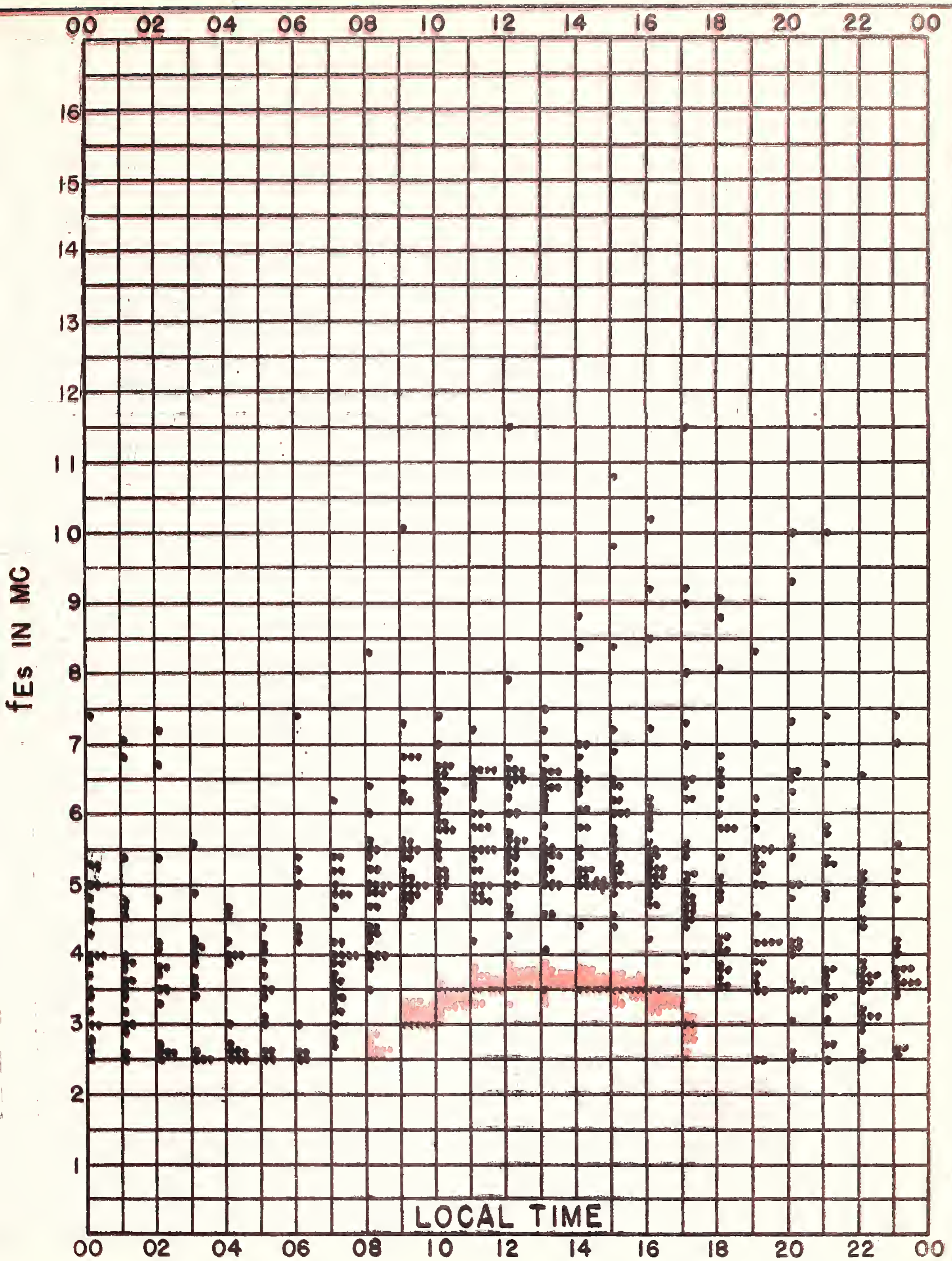

Fig.49. LEYTE, PHILIPPINE IS. JUNE, 1945

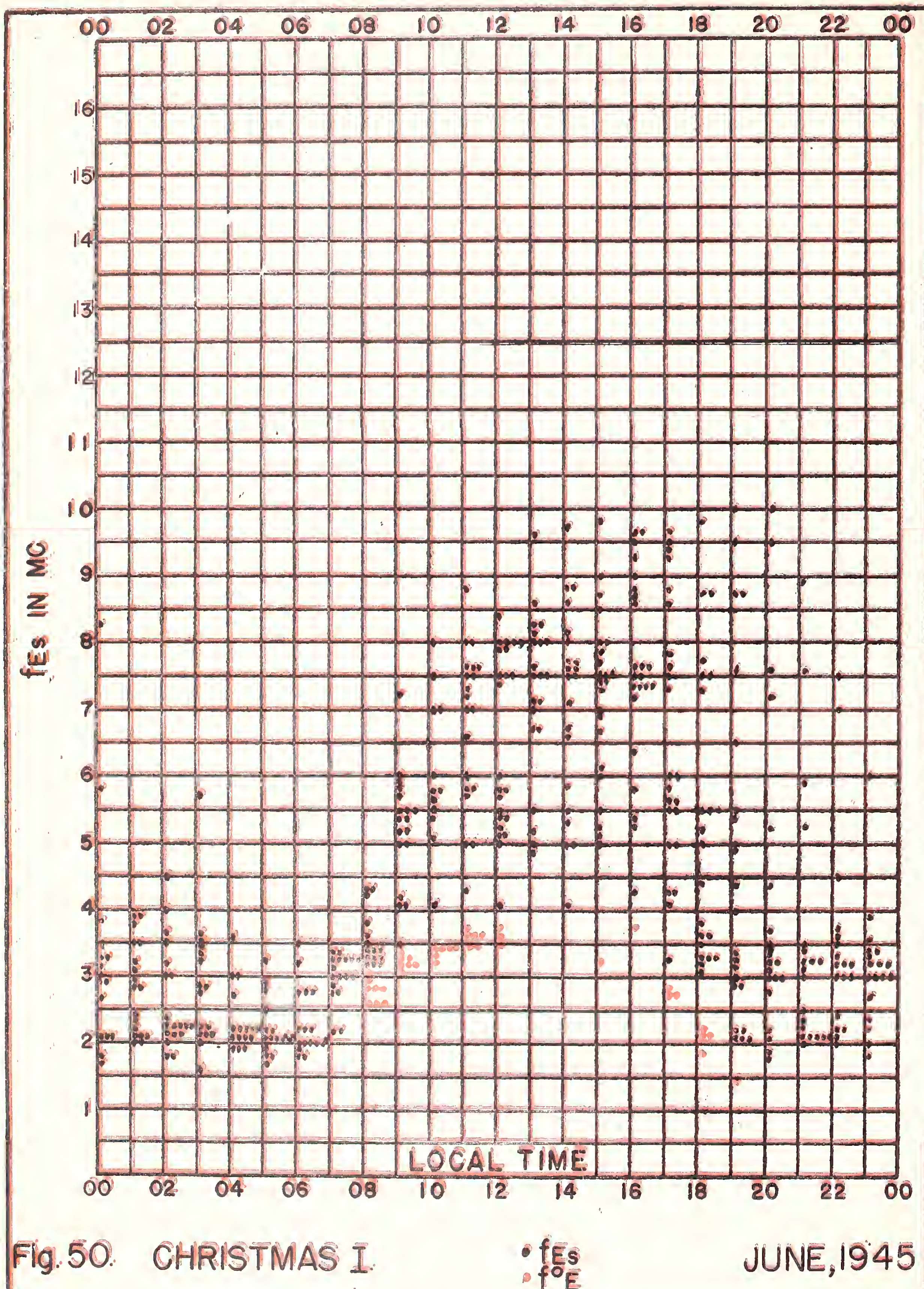

Fig. 50. CHRISTMAS I. JUNE, 1945

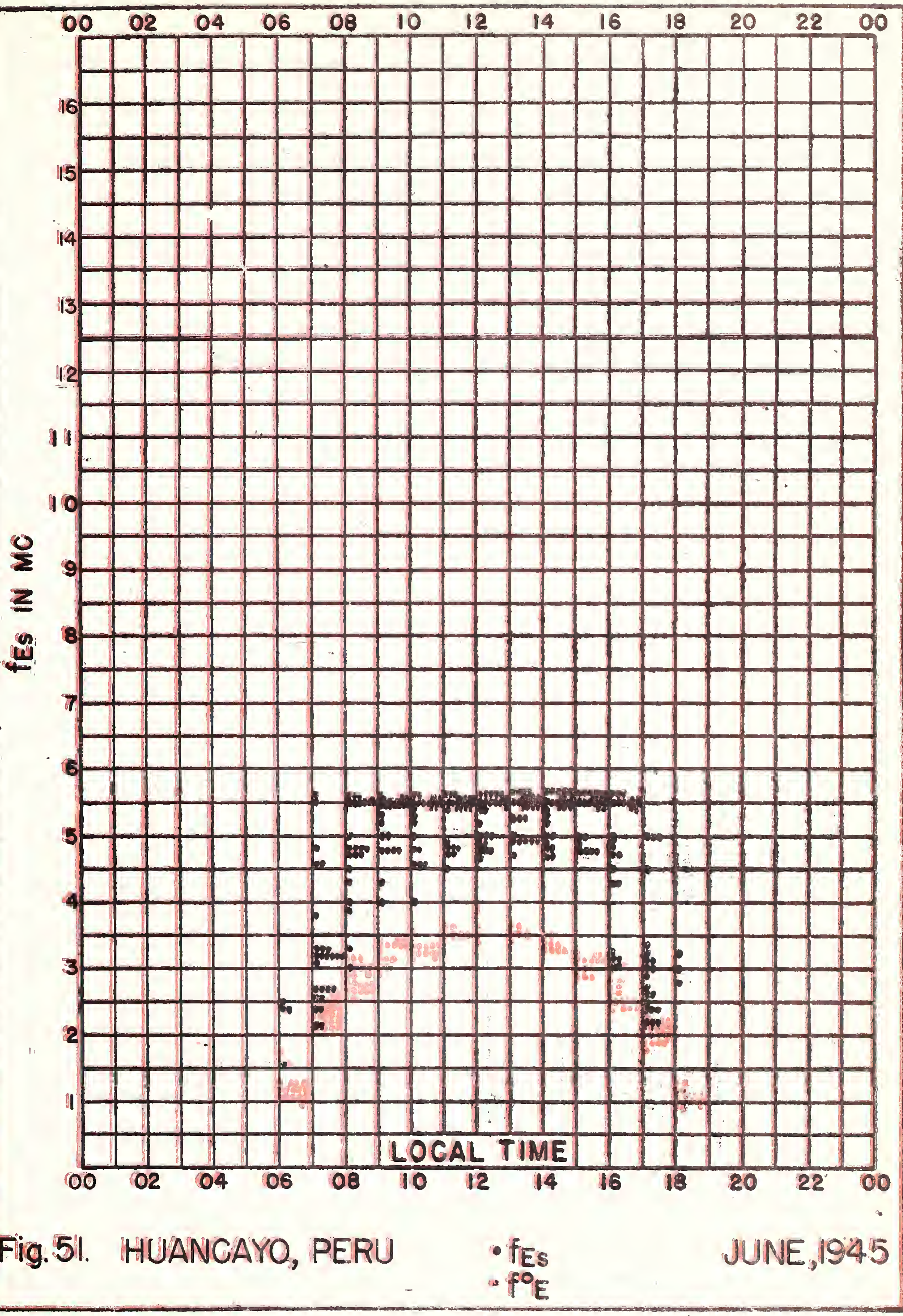

Fig. 51. HUANCAYO, PERU JUNE, 1945

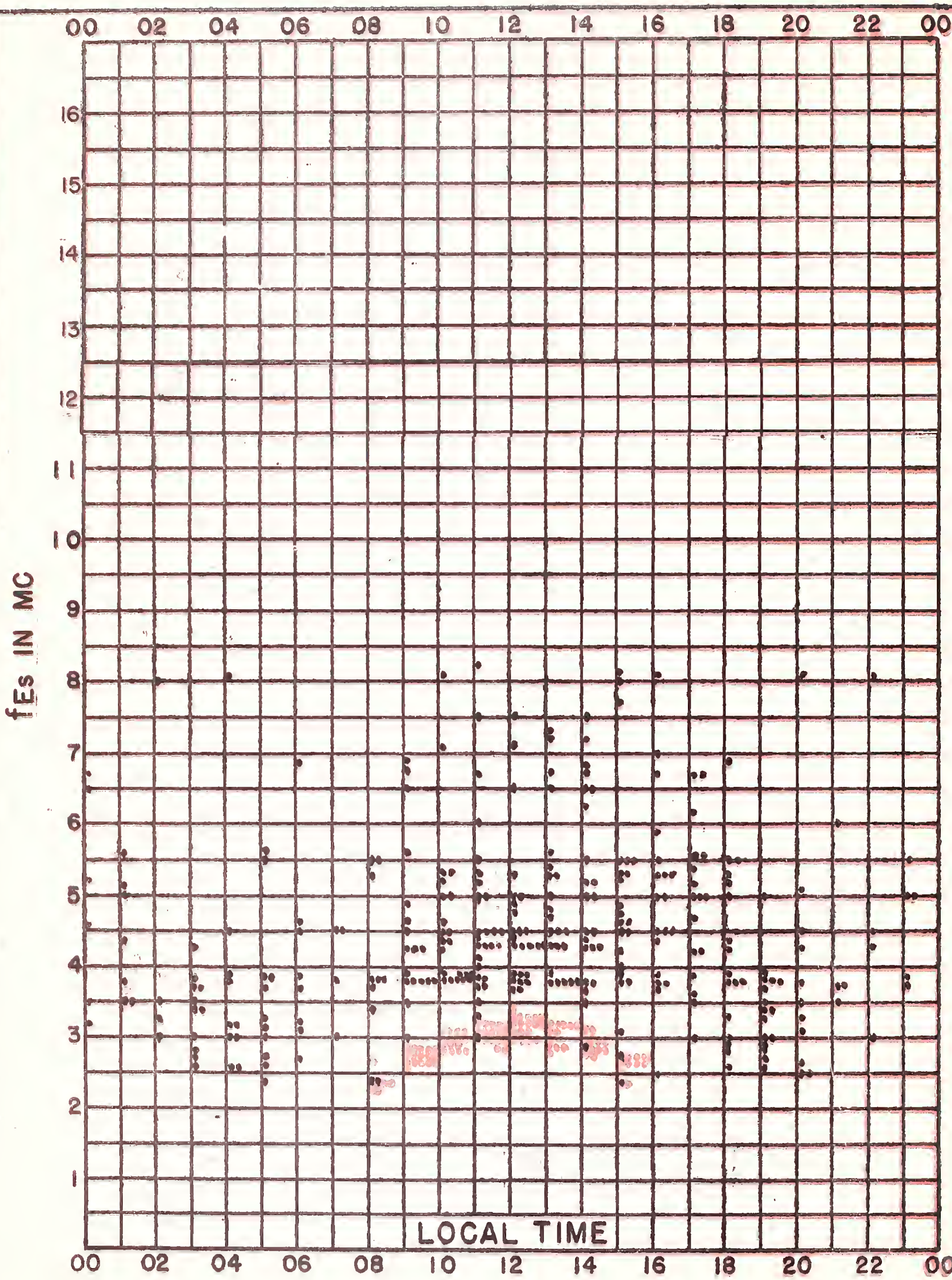

Fig. 52. BRISBANE, AUSTRALIA JUNE, 1945

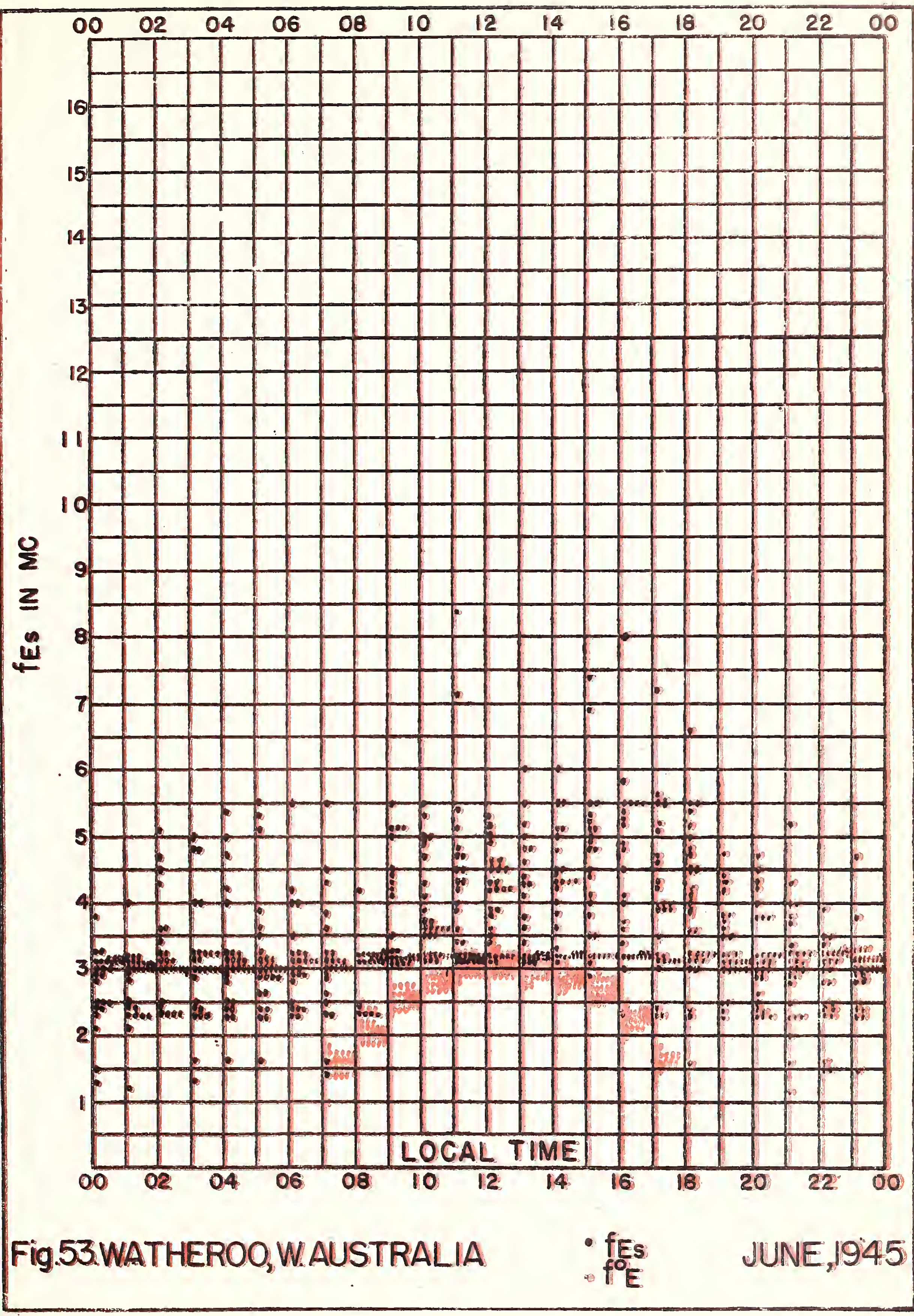

Fig.53. WATHEROO, W. AUSTRALIA JUNE, 1945

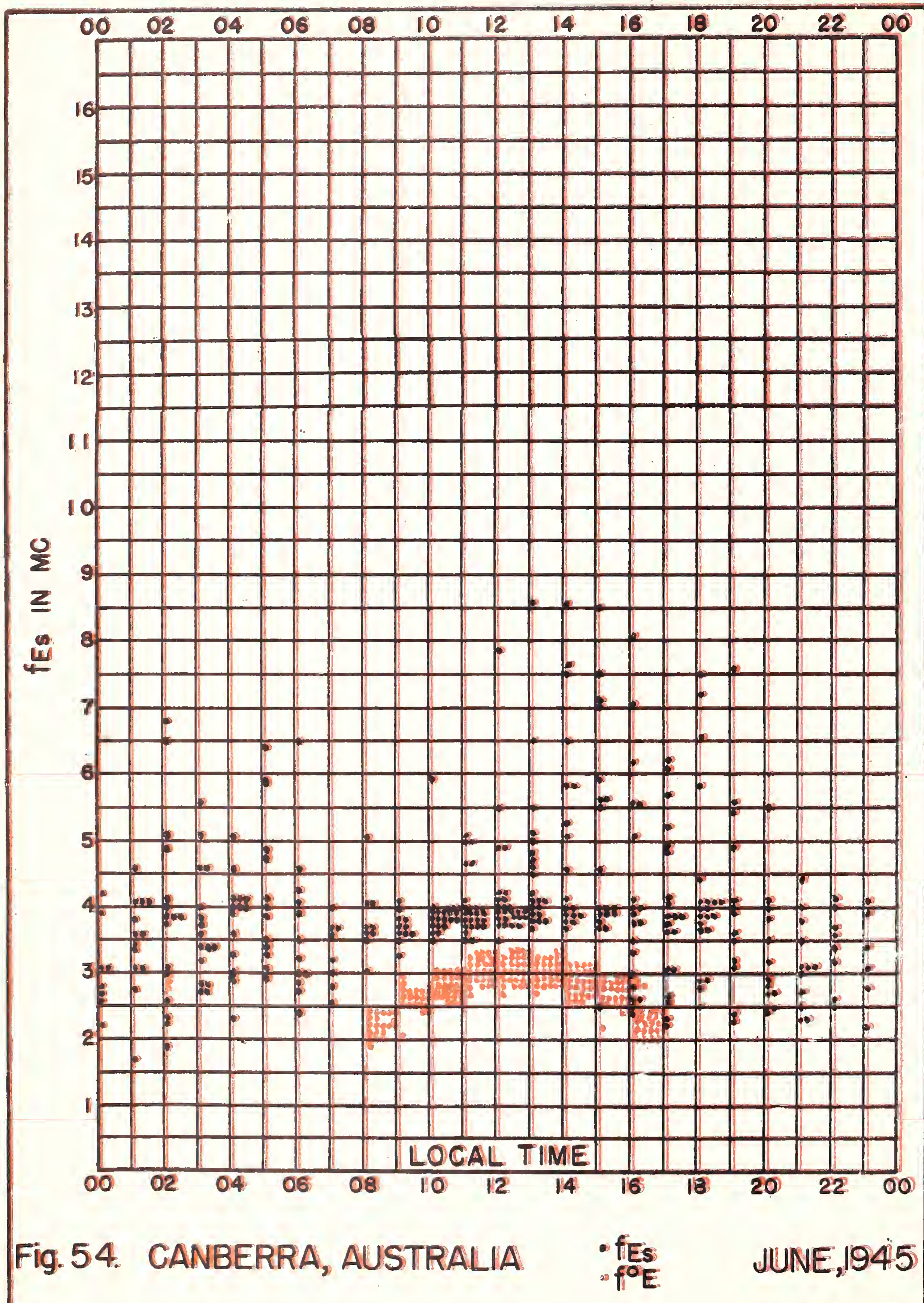

Fig. 54. CANBERRA, AUSTRALIA JUNE, 1945

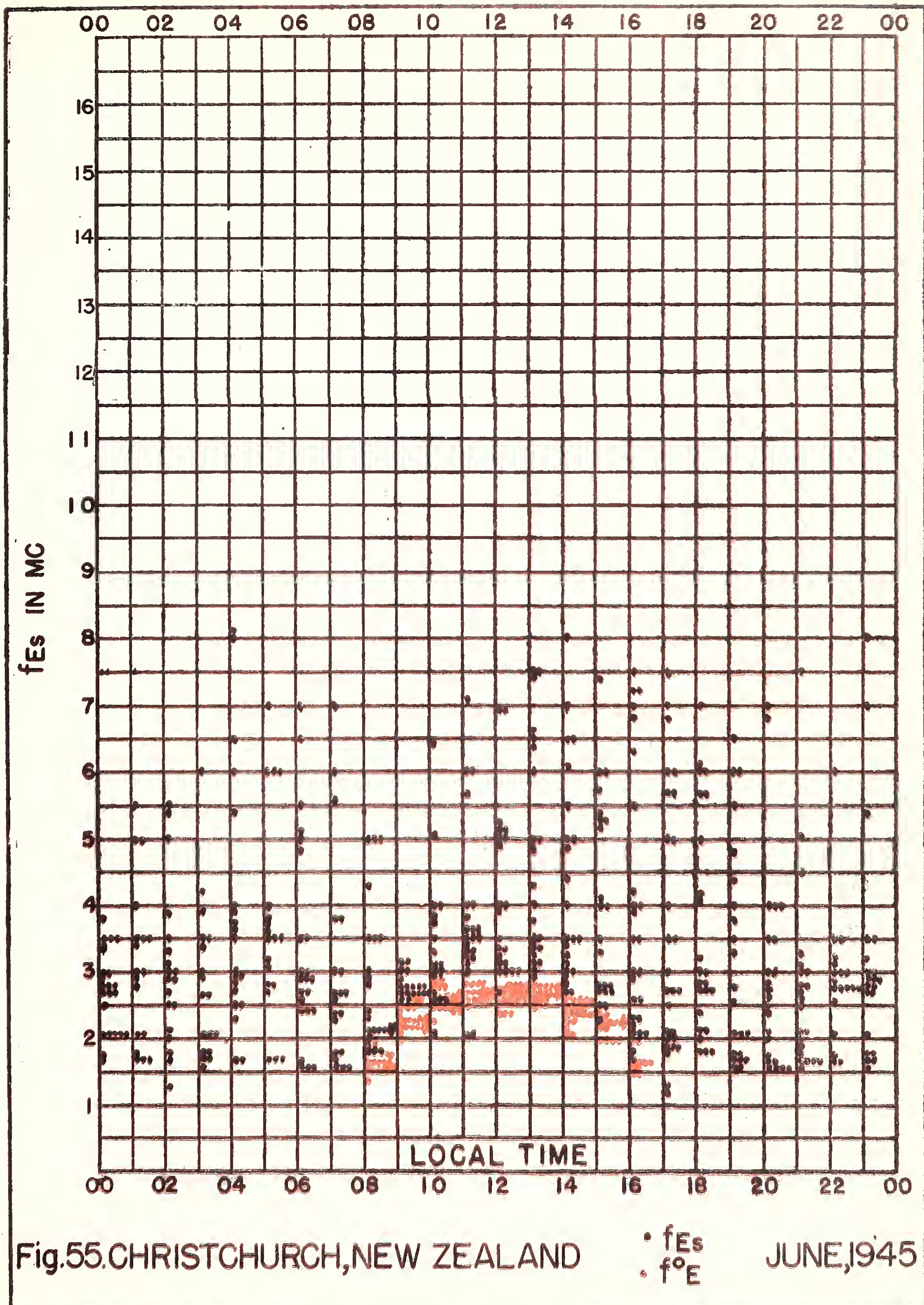

Fig.55. CHRISTCHURCH, NEW ZEALAND JUNE, 1945

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Issued
10 April 1946

Comparison of Percentage of Total Time of Occurrence of Second-Multiple Es Reflections and That of fEs in Excess of 3 Mc.

An interesting discrepancy in the long-time trends of sporadic-E ionization seems to exist between data obtained at Watheroo, W. Australia, and those observed at Washington, D.C. This was previously noted in the report "Ionospheric Data," IRPL-F12, in an article "Sporadic-E Variation with Intensity and Latitude of Solar Activity." Observations of fEs made at Washington, D.C. indicate both seasonal and solar-cycle variations which are consistent with the idea that sporadic-E ionization is principally caused by solar radiation, probably corpuscular, emanating from regions near the center of the solar disc. Since solar activity is largely concentrated near solar equatorial regions during minimum periods of solar activity, sporadic-E ionization is a maximum during periods of sunspot minimum, and vice versa, according to this theory.

Values of fEs at Watheroo, W. Australia, prior to March 1944 were not scaled. Occurrence of second-multiple reflections from Es were, however, noted, and the percentage of total time during which they occurred was reported to reach a maximum in 1941, - about three years previous to the minimum of solar activity.

Since the data concerned in the establishment of this time trend at Watheroo are not directly comparable with those used for establishing the Washington time trend, it is interesting to investigate both comparisons of fEs as observed at both Washington, D.C., and at Watheroo, W. Australia, and comparisons of fEs and second-multiple reflections from Es at the latter station over the period of time for which data on both are available.

Figs. 11 through 13 present mass plots of fEs observed at Washington, D.C. during the months of December 1944, and April and June 1945. Inspection of the distribution of values shows them to be generally skewed toward the higher frequencies, but with fairly regular graduation throughout. Figs. 14 through 16 present mass plots of fEs observed at Watheroo, W. Australia. In these, the graduation of distribution is far from even, concentration of the distribution occurring near frequencies where band changes are made in the frequency sweep. This indicates marked change in either radiated power or receiver sensitivity in the recorder at these frequencies, or both, with consequent modification of the recorded value of fEs. In such cases, corresponding error exists in the determination of monthly median values of fEs,

(over)

or time percentages of the occurrence above a chosen frequency limit, and therefore in trends based upon these quantities.

Daily values, for each hour, of upper-limit second-multiple reflection frequencies for vertical reflections from sporadic-E ionization were not available, but only the percentages of total time of occurrence above 0.5, 5, and 10 Mc. ("Sporadic E-Region Ionization at Watheroo Magnetic Observatory, 1938-1944", Report No. 6 under Contract NXsr-33809, by H. W. Wells, Department of Terrestrial Magnetism, Carnegie Institution of Washington, August 6, 1945). It might be expected that these would bear a nearly constant ratio to those obtained for percentage of time of occurrence of fEs above a designated frequency limit, provided that absorption effects were negligible.

Figs. 1 through 10 present values of the ratio of the percentage of total time of occurrence of vertical-incidence second-multiple reflections from sporadic-E ionization above 0.5 Mc to the percentage of time of occurrence of fEs above 3 Mc, at each hour of the day, for the months of March through December 1944 during which both of these types of data were available.

It is to be noted that the above ratio is far from constant, for all of these months. Its variation is characterized by relatively high values during night hours, and low values near midday, thus indicating that recorded values of vertical second-multiple reflection limits of frequency are greatly influenced by absorption phenomena, and therefore cannot be expected to manifest trends of the type shown by fEs.

It is particularly noteworthy that the highest night values of this ratio occur during equinox seasons. This is interesting, since sporadic-E ionization is a minimum during these seasons, because it suggests that nighttime absorption, caused by ionization which varies as does sporadic-E ionization, is appreciable. It would thus seem that absorption during periods of ionospheric storminess, probably caused by solar corpuscular emission, according to the theory of sporadic-E ionization mentioned earlier in this report, is very likely a related phenomenon.

If absorption of second-multiple sporadic-E vertical-incidence reflections is, as it seems, dependent upon the amount of sporadic-E ionization present, it is not surprising that a maximum in the percentage of total time of vertical-incidence second-multiple Es reflections should have occurred before that in the percentage of total time of fEs above any selected frequency, - the seeming discrepancy between long-time trends of these quantities noted at the beginning of this report. An optimum condition for high percentage of occurrence of second-multiple vertical-incidence Es reflections should occur when Es is prevalent (i.e., probably nearer sunspot minimum than sunspot maximum), but, before its prevalence is sufficient to cause absorption in amounts diminishing the observation of the second-multiple Es reflections.

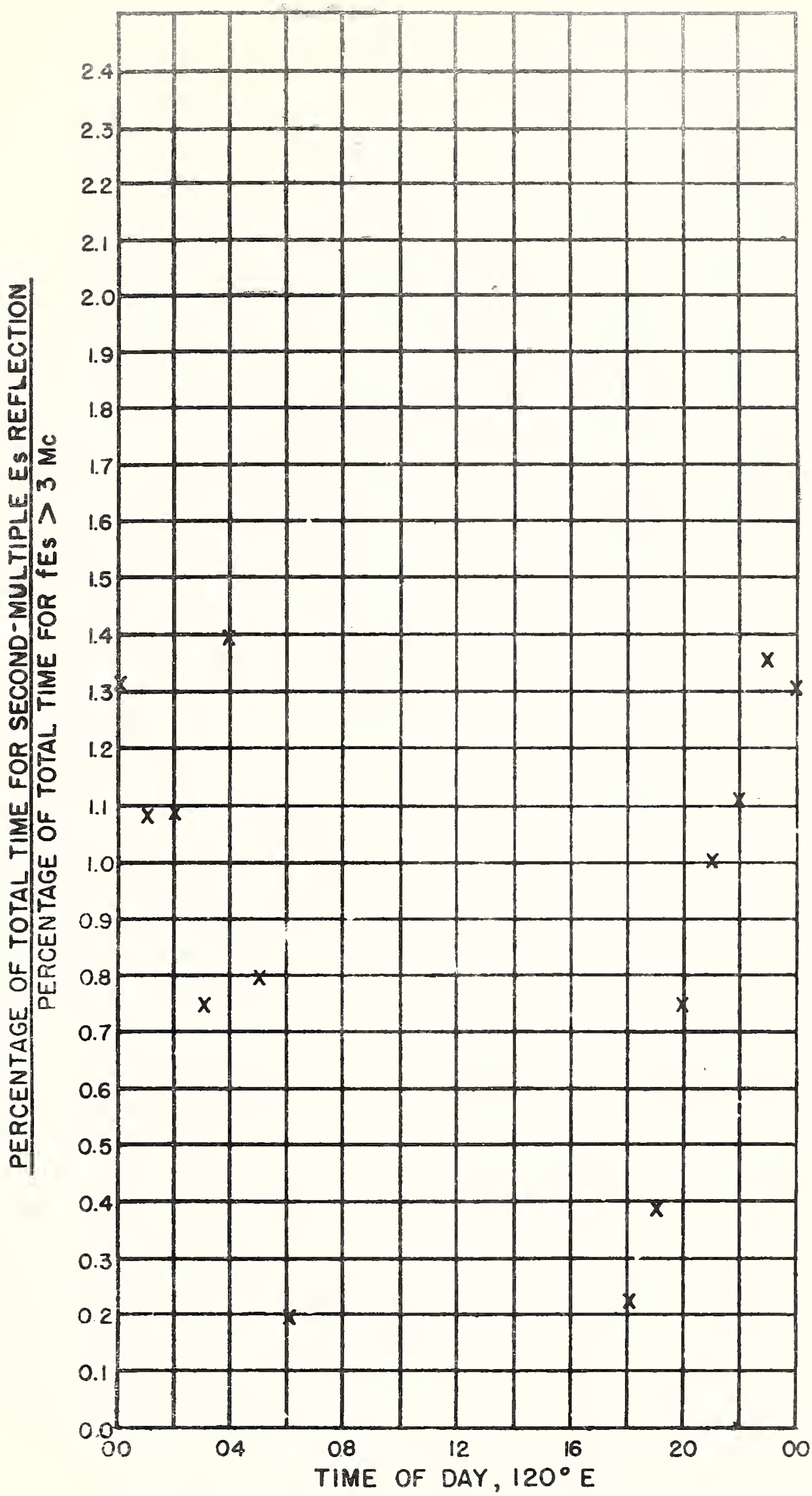

Fig. I. WATHEROO, W. AUSTRALIA
MARCH, 1944

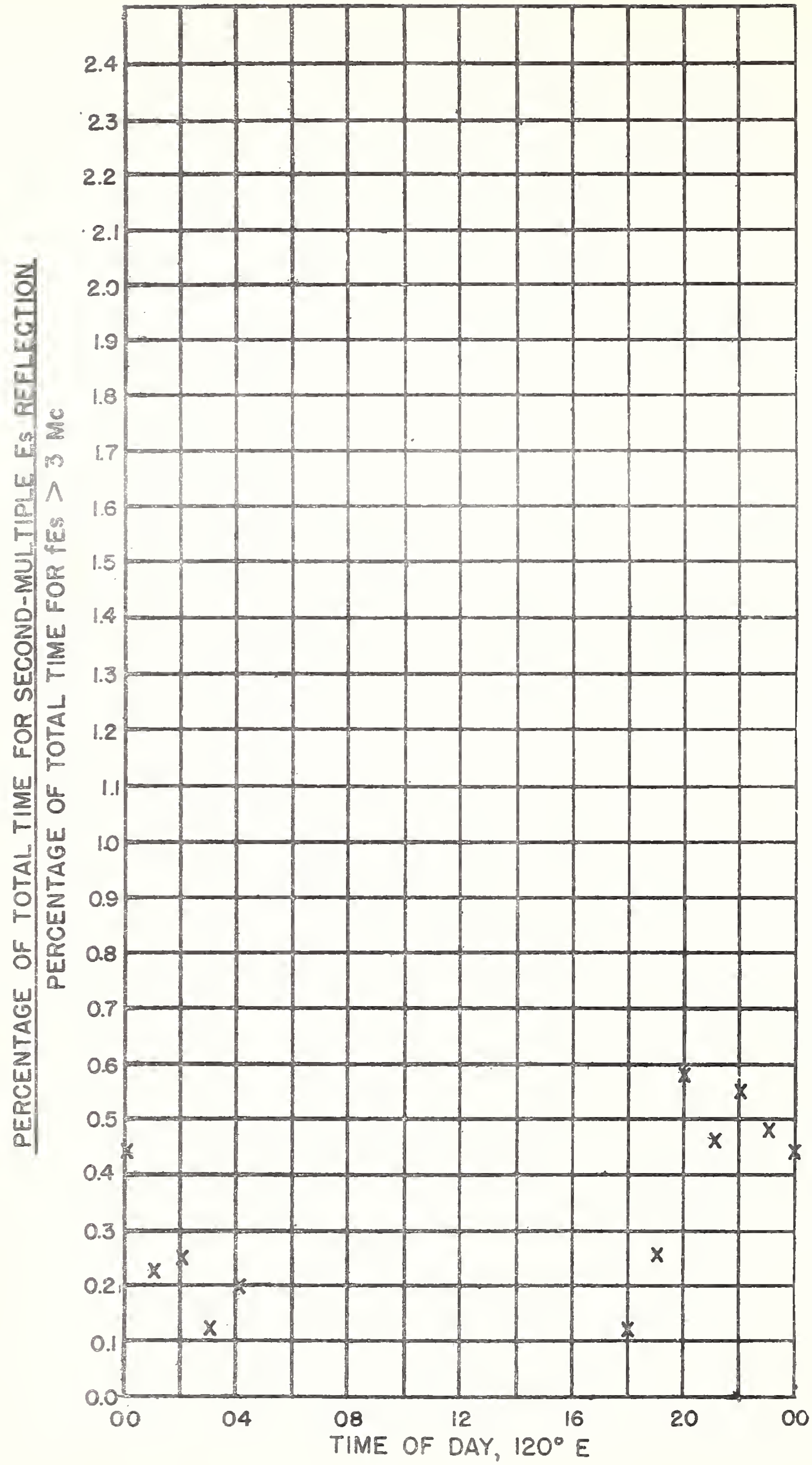

Fig. 2. WATHEROO, W. AUSTRALIA
APRIL, 1944

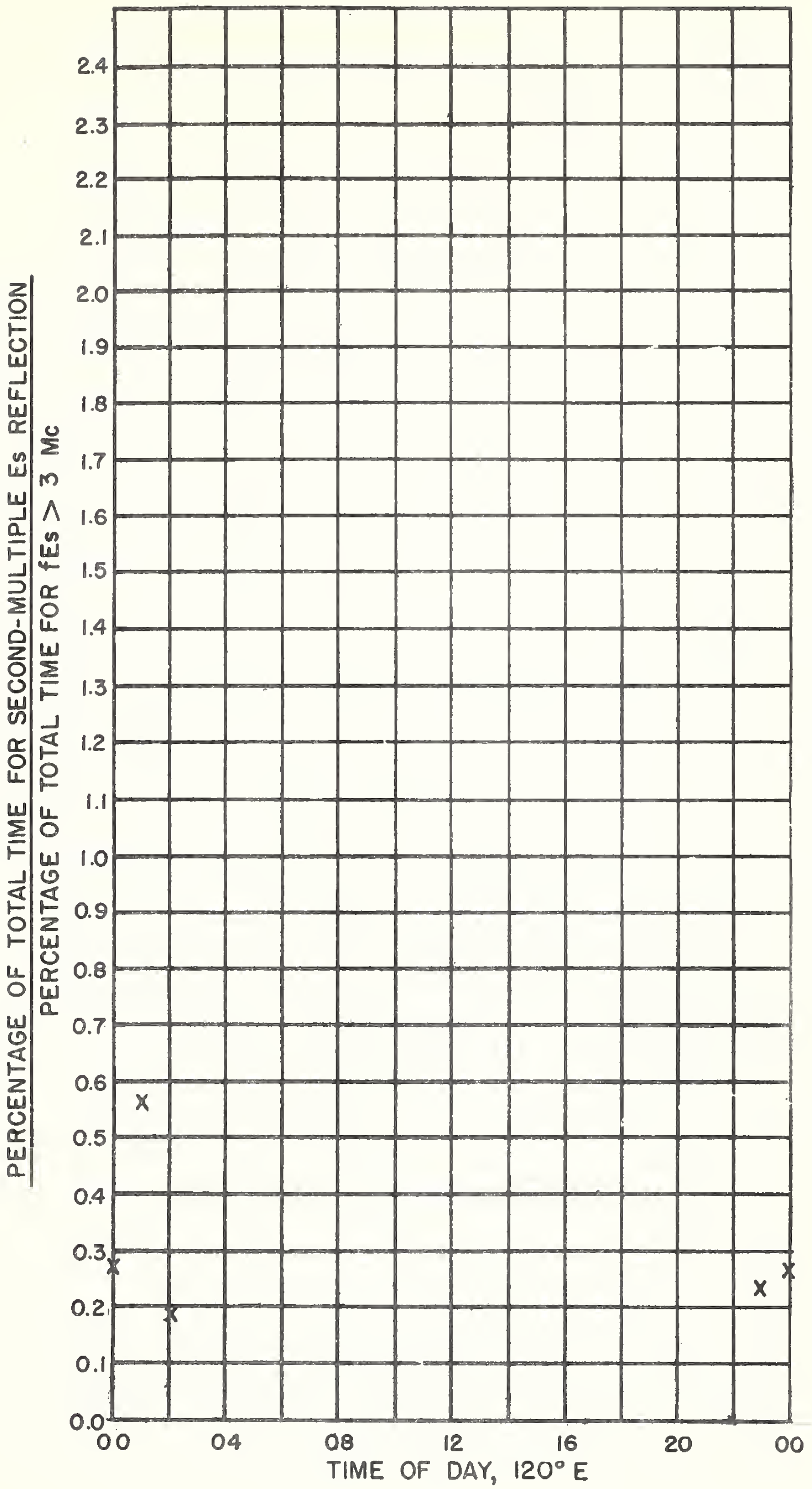

Fig. 3. WATHEROO, W. AUSTRALIA
MAY, 1944

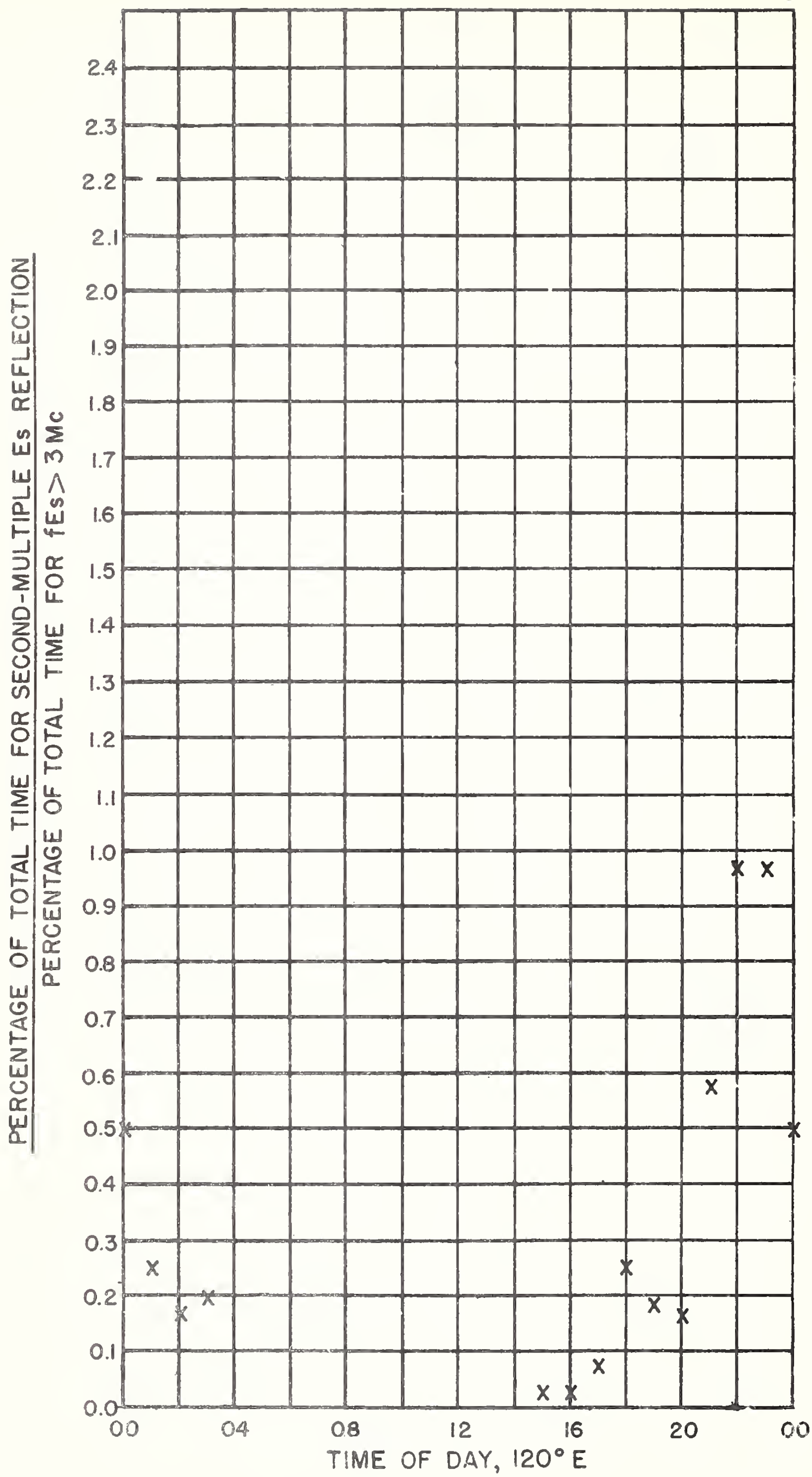

Fig. 4. WATHEROO, W. AUSTRALIA
JUNE, 1944

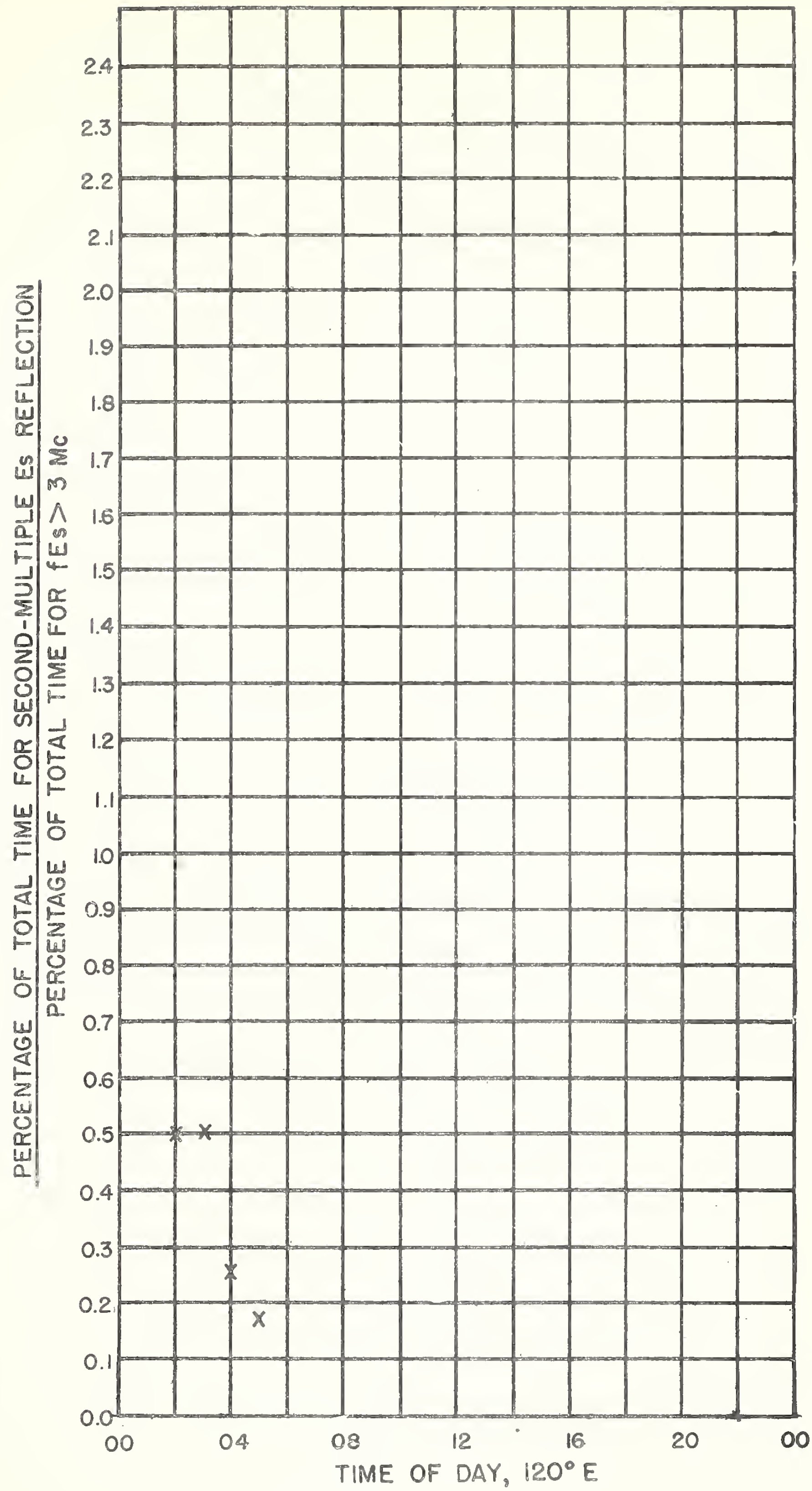

Fig. 5. WATHEROO, W. AUSTRALIA
JULY, 1944

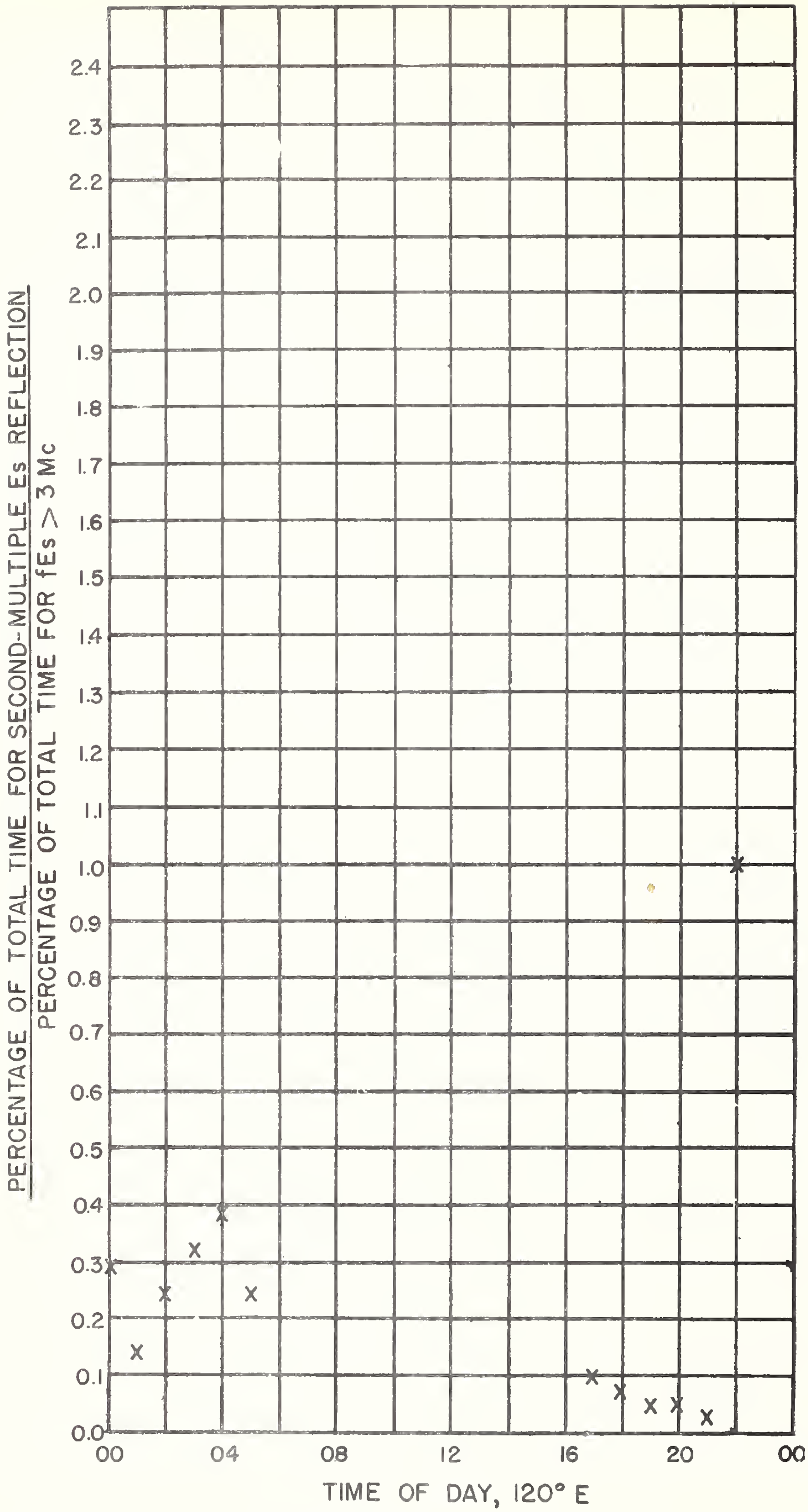

Fig. 6. WATHEROO, W. AUSTRALIA
AUGUST, 1944

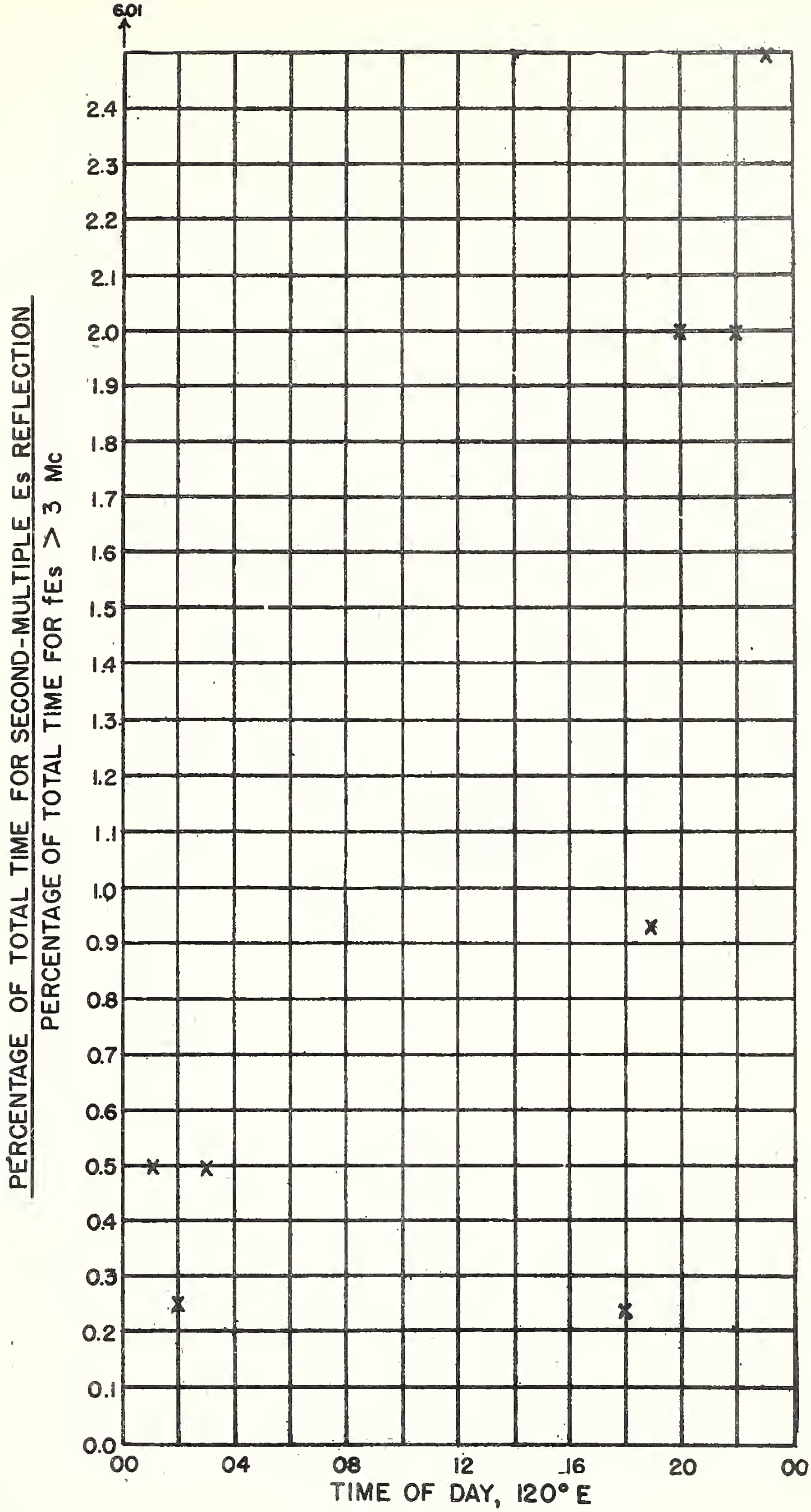

Fig. 7. WATHEROO, W. AUSTRALIA
SEPTEMBER, 1944

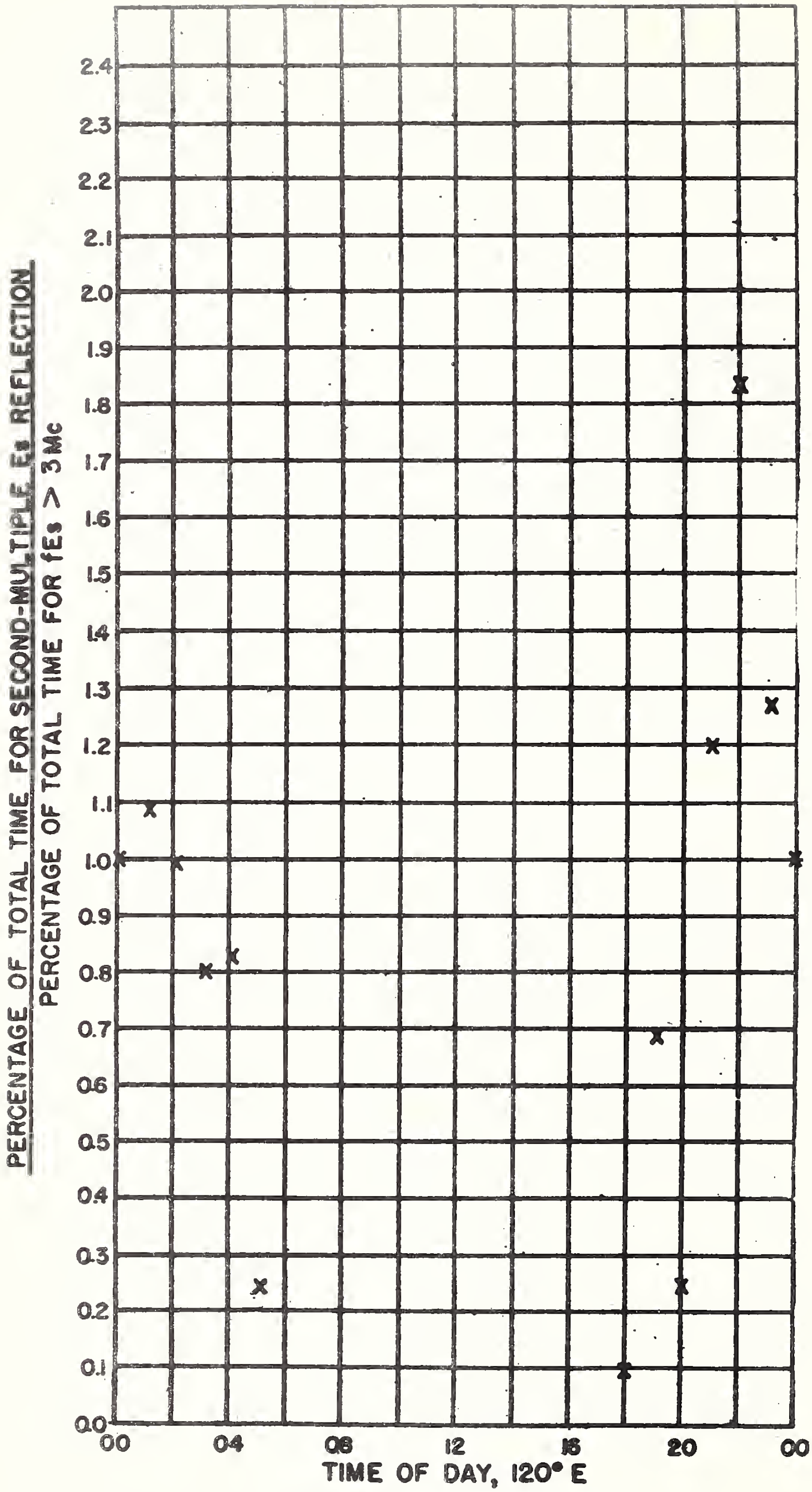

Fig.8. WATHEROO, W. AUSTRALIA
OCTOBER, 1944

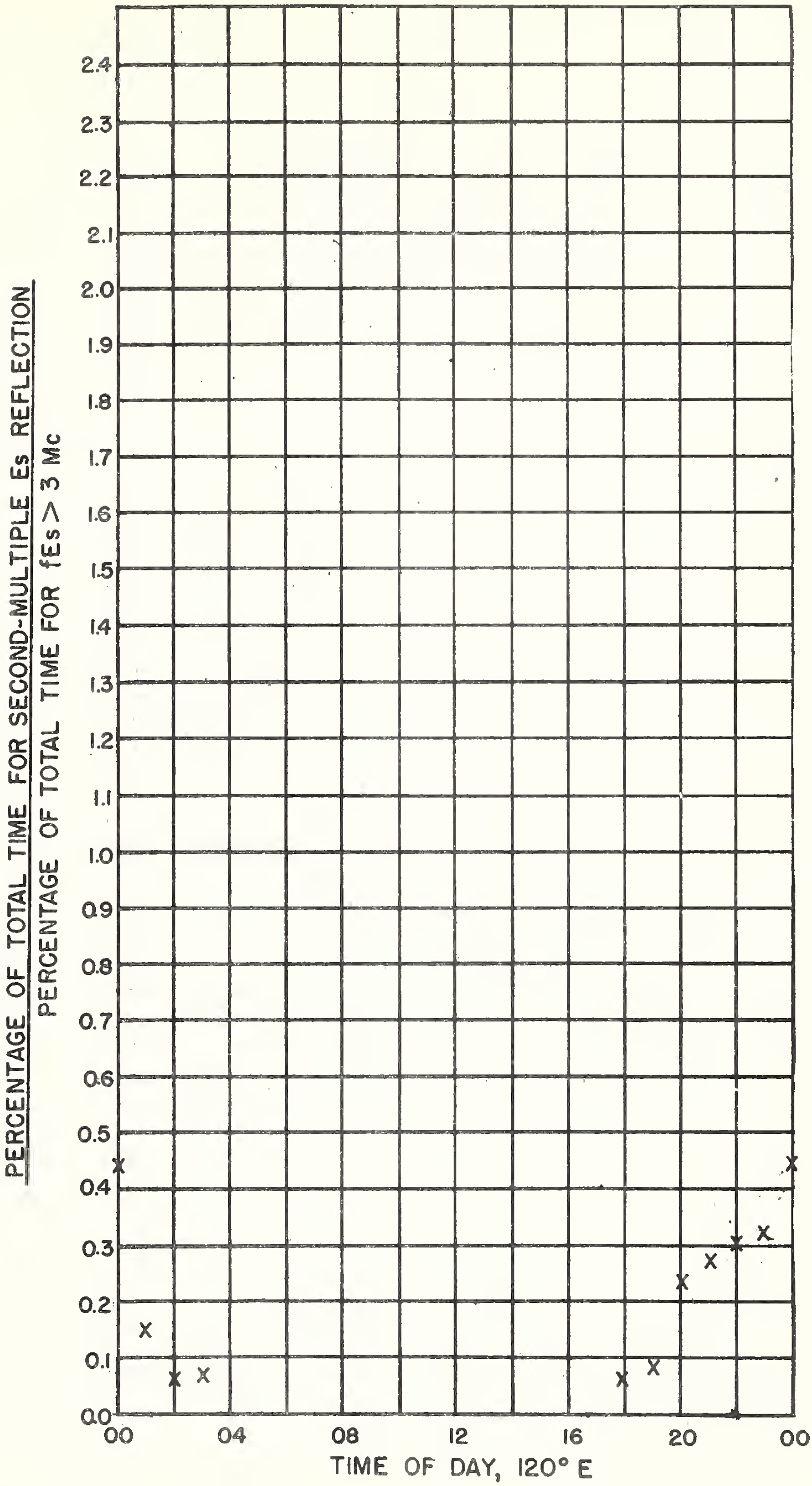

Fig.9. WATHEROO, W. AUSTRALIA
NOVEMBER, 1944

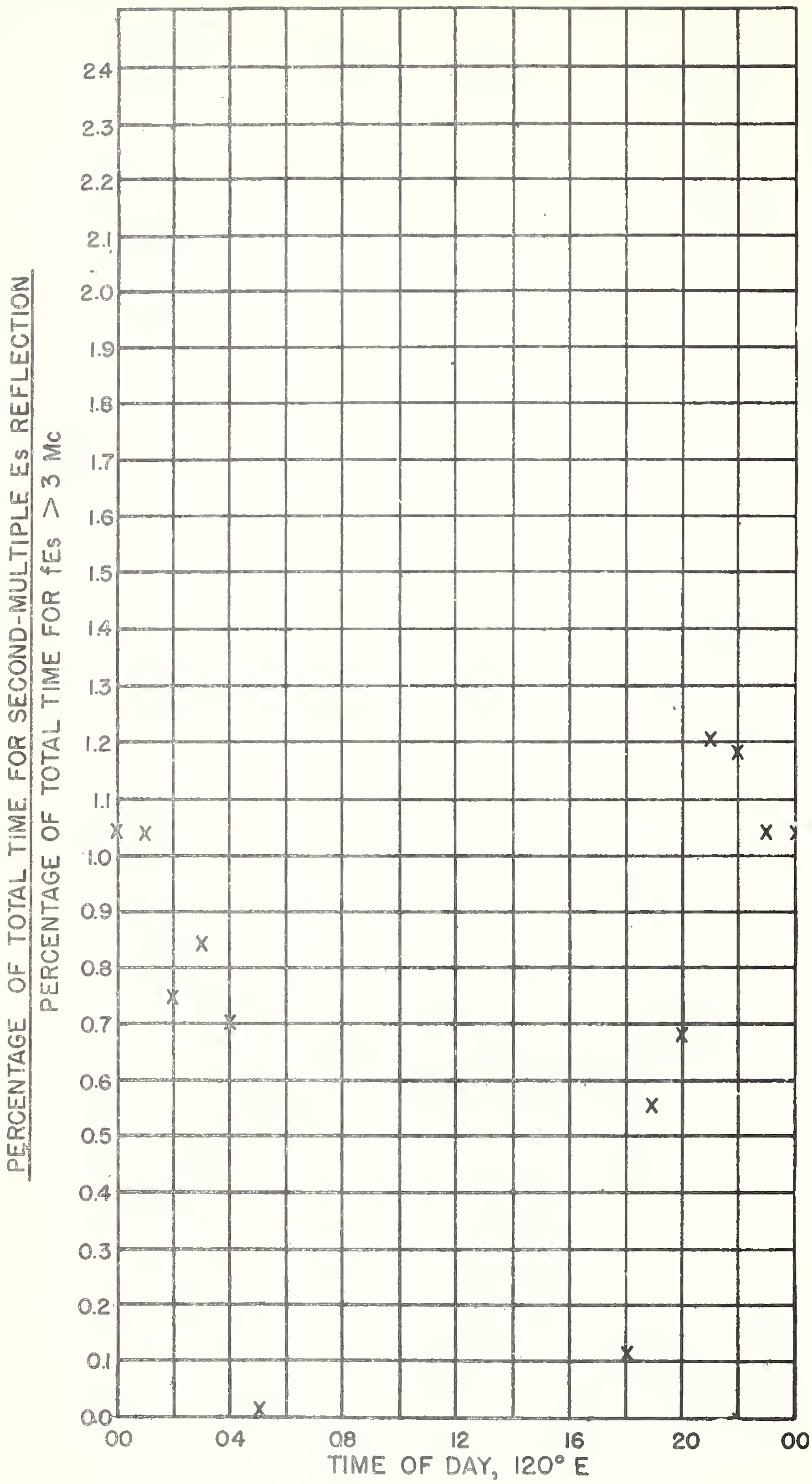

Fig.10. WATHEROO, W. AUSTRALIA
DECEMBER, 1944

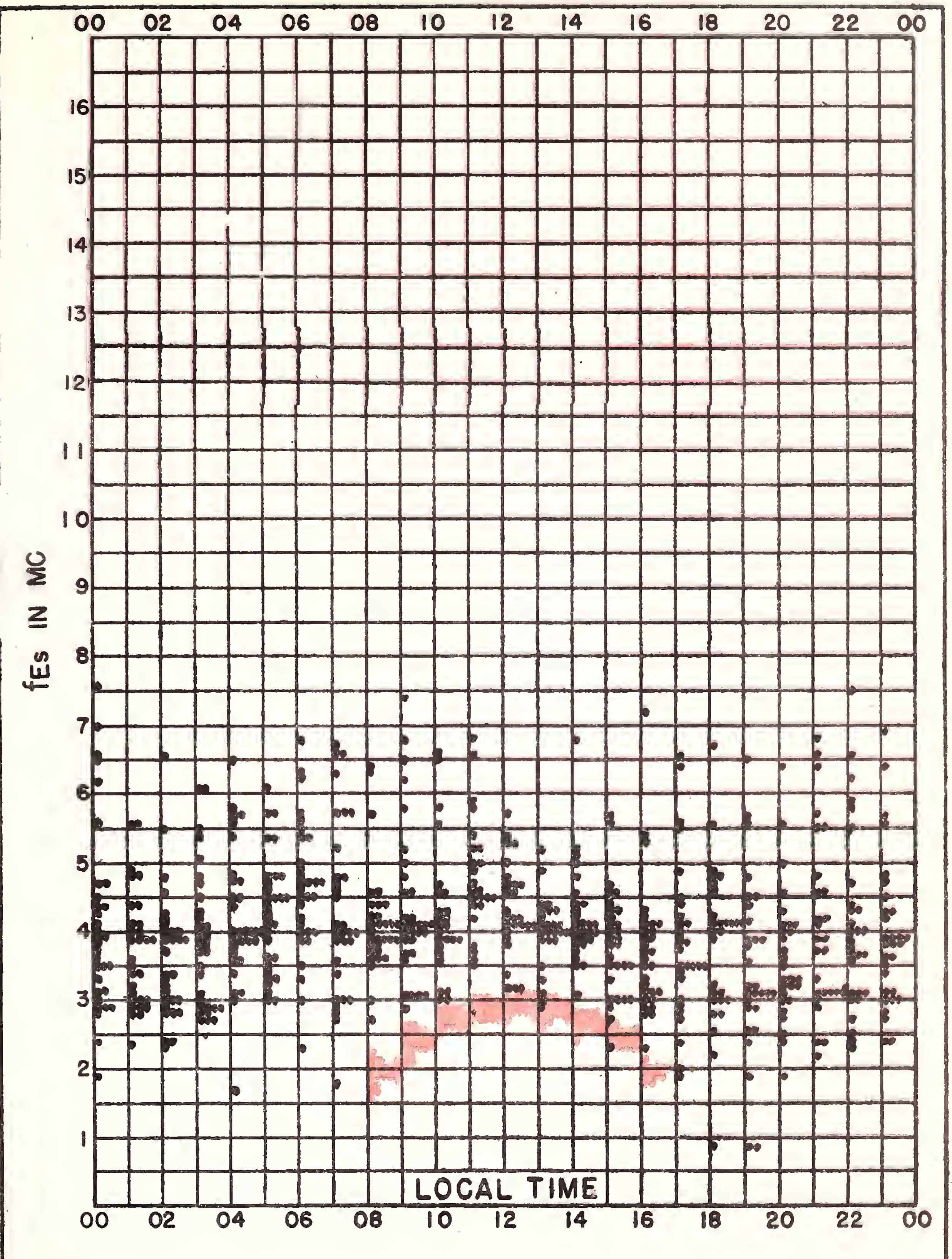

Fig. 11. WASHINGTON, D.C. DECEMBER, 1944

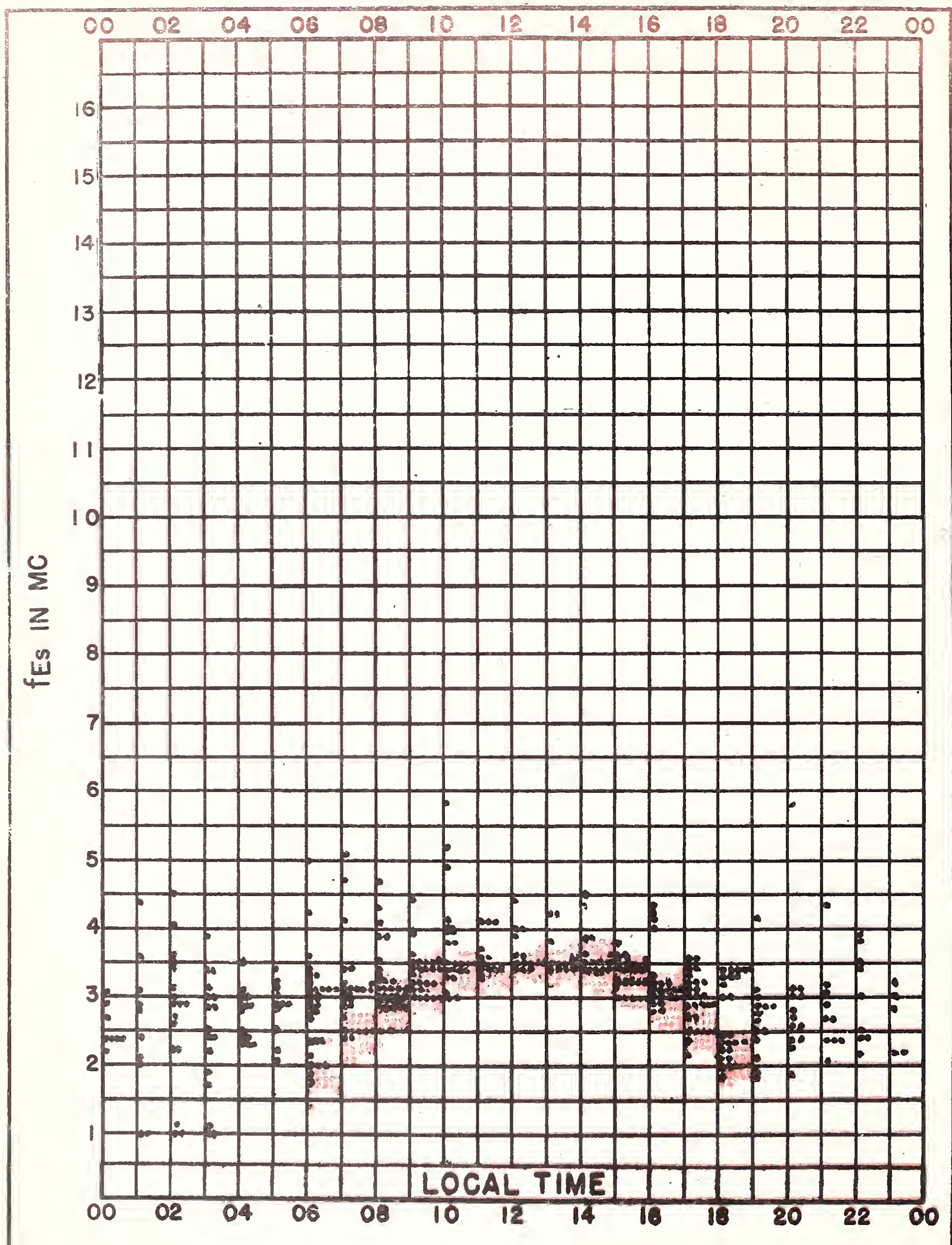

Fig. 12. WASHINGTON, D.C. APRIL, 1945

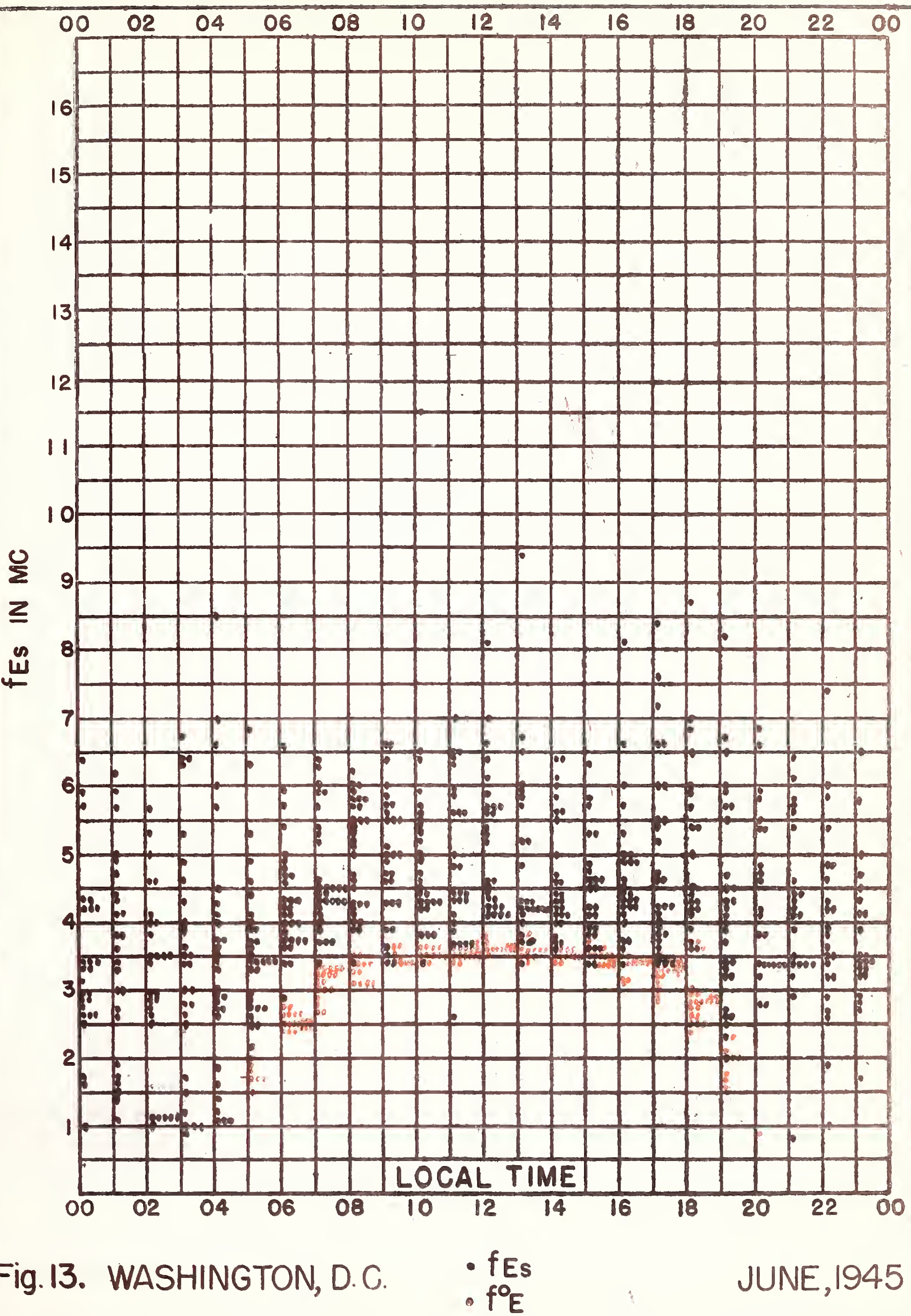

Fig. 13. WASHINGTON, D.C. JUNE, 1945

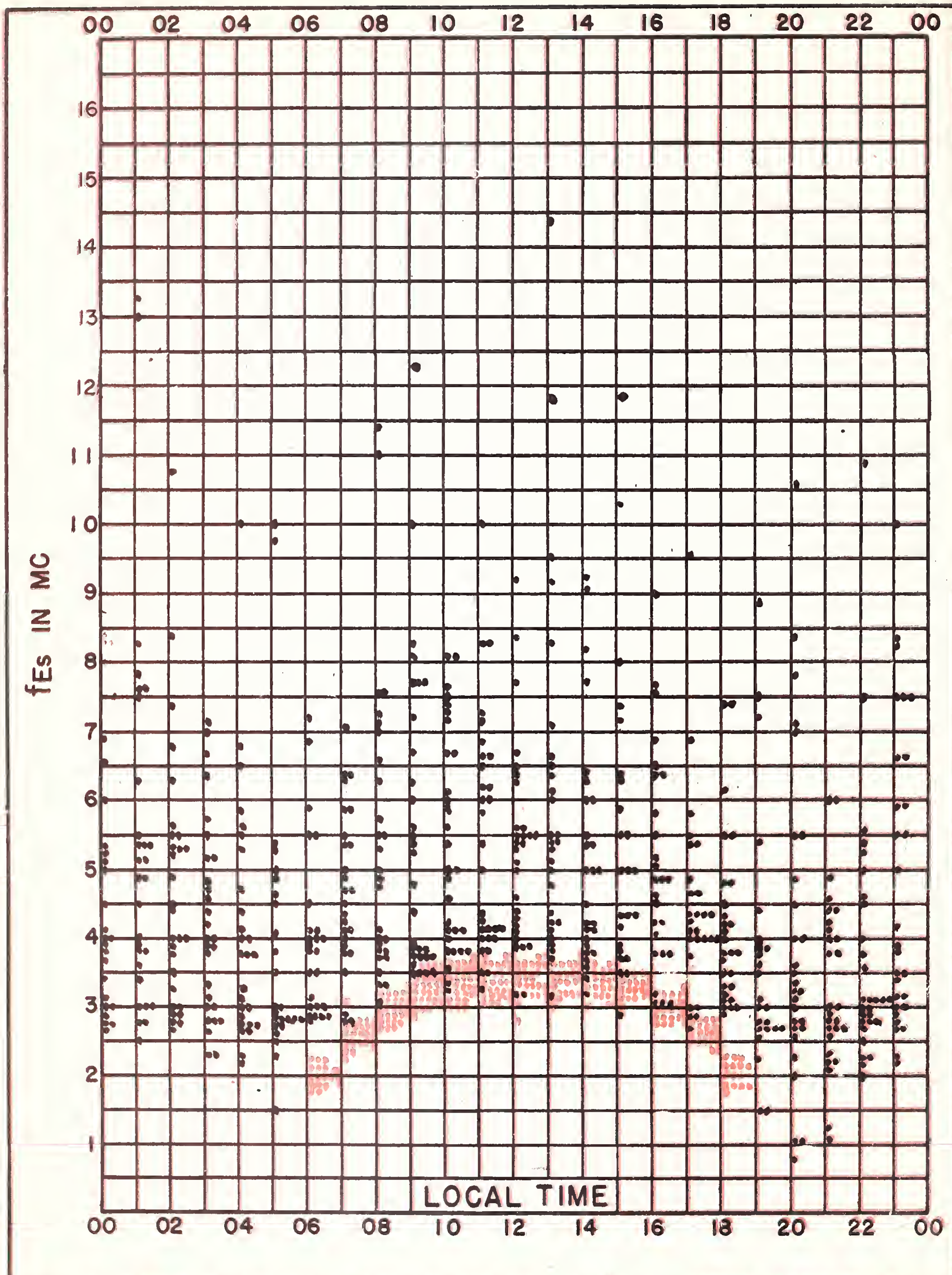

Fig. 14. WATHEROO, W. AUSTRALIA DECEMBER, 1944

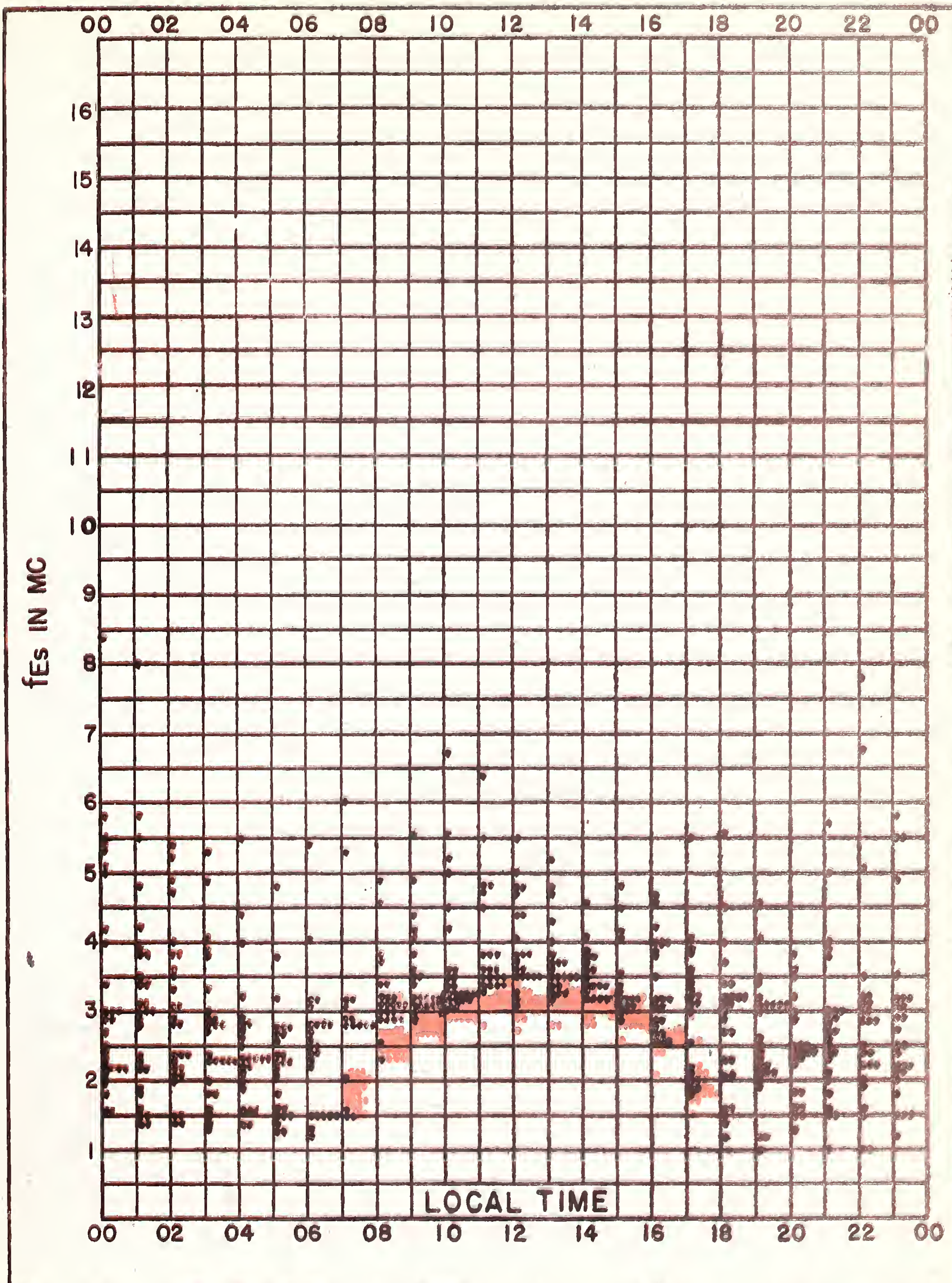

Fig. 15. WATHEROO, W. AUSTRALIA APRIL, 1945

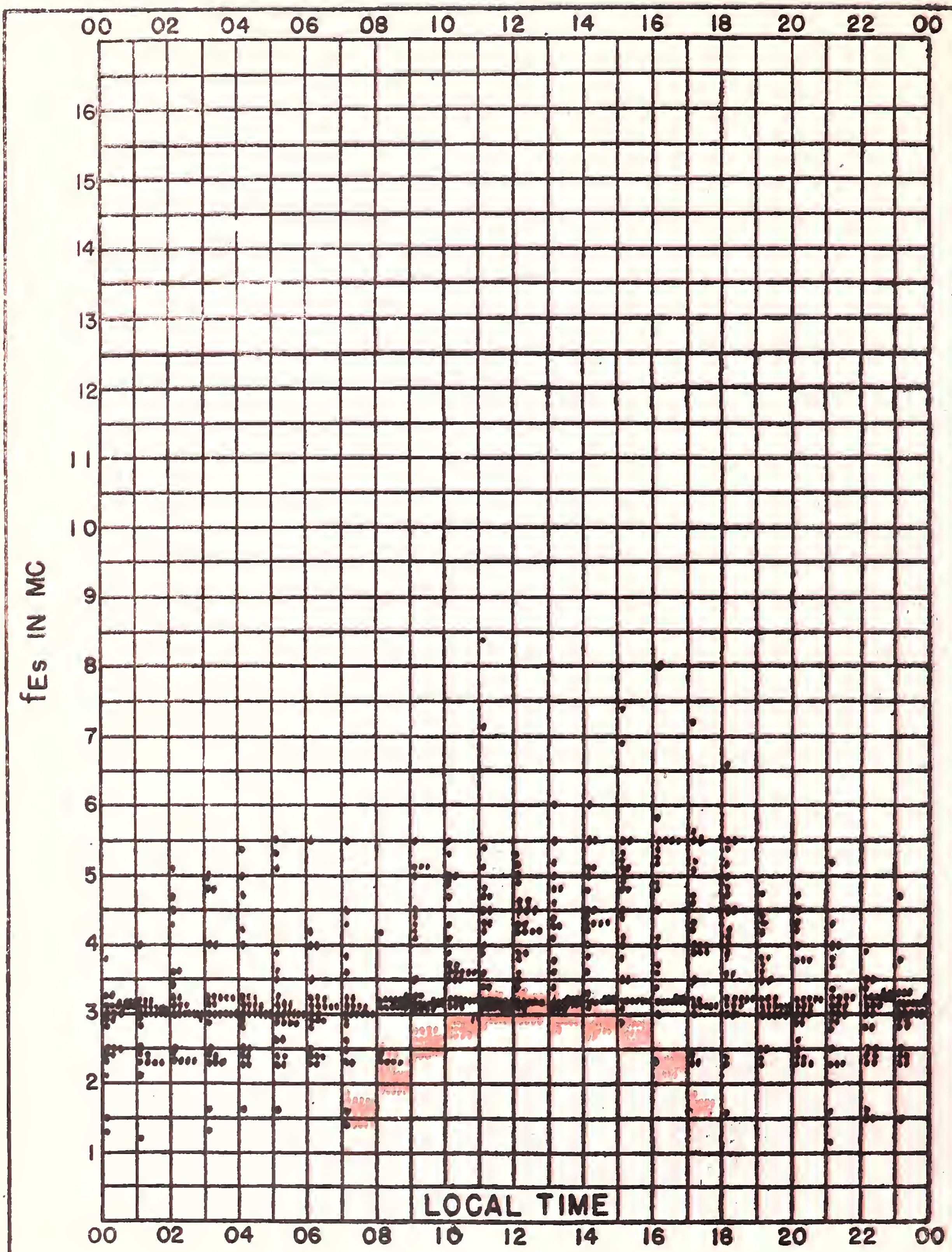

Fig. 16. WATHEROO, W. AUSTRALIA JUNE, 1945