Fire Research Note

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THE EFFECT OF RE-SITING FIRE STATIONS ON ATTENDANCE
TIMES AT FIRES IN BUILDINGS IN COUNTY BOROUGHS

by

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FIRE
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STATION

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SUMMARY

New fire stations have been brought into operation either as replacements, or as additions to existing fire stations. An attempt has been made to measure the effectiveness of these changes in sixteen County Boroughs,

Monthly mean attendance times at fires in buildings have been examined over a period of years both before and after the re-siting for each brigade.

If the trend in attendance times over the whole period examined remained constant, the data have been analysed to determine whether a significant shift in the trend line took place at the time of the change.

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JOINT FIRE RESEARCH ORGANIZATION

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Introduction

During the last few years, a number of County Borough fire brigades have
opened new premises. Some of these changes were necessitated by factors outside
the control of the brigades, e.g. stations had occupied what were temporary war-
time sites and these sites were otherwise required.

In this investigation an attempt has been made to compare monthly mean atten-
dance times after the change with those before.

Method

Information was obtained as to the dates on which new fire stations were
opened and the changes in fire cover that took place. The changes in fire cover
were as follows:-

(i) The replacement of an existing station

(ii) The replacement of two stations by a single station

(iii) An additional station to those already in operation

Time was related to the date when the change took place; monthly mean
attendance times at fires in buildings (other than late calls) being calculated
for each brigade over a period of years, extending for two or three years either
side of the date of change. The actual periods investigated in the different
brigades were, therefore, not identical. In brigade E there was a period over
which the brigade had to work from five stations, one less than their normal
complement, because a station had to be closed before the replacement station
became operational. In this brigade, time before the change was measured
relative to the closure and time after the change was measured relative to the
opening; the period between the closure and opening was ignored.

In the cases where only one of several stations was altered, all of the fires
in buildings throughout the brigade area (other than late calls) were included in
the analysis in order to increase the number of fires analysed. The more data
there are to be analysed, the greater the possibility of assessing whether changes
reflected by the data did not occur purely by chance. In any case, station
boundaries may have been revised at the time of the change in station siting, and
this can be ignored by analysing the whole brigade area.

Most brigades appeared to show seasonal fluctuations in monthly mean atten-
dance times. To examine the true behaviour of the monthly mean attendance times,
these seasonal variations were removed by means of a "moving average" technique
(see Appendix).

For the purpose of statistical analysis, it was desirable for the errors of
the monthly mean attendance times (whether or not they be seasonally adjusted)
to be normally distributed about the moving average. In five brigades this was
not so, hence the data on monthly mean attendance times were transformed in such
a way that these errors became more normally distributed.

The data from each of the sixteen brigades were analysed by one of three methods:-

(i) By fitting a regression line to monthly mean attendance times.

(ii) By fitting a regression line to seasonally corrected monthly mean attendance times.

(iii) By fitting a regression line to seasonally corrected monthly mean attendance times transformed by means of a square root transformation.

For each brigade a graph (see Figs 1-16) has been drawn showing the regression lines before and after the change of fire cover, and the appropriate set of monthly means, i.e. uncorrected or seasonally adjusted. The variation about the regression lines is dependent both upon the topography and size of the station areas and upon the number of fires occurring each month in the brigade area. If only a few fires occur each month the chances are higher that they will either all be calls requiring a long journey or all be calls requiring a short journey, than when a large number of fires occur each month.

The slopes of the regression lines were assumed to be equivalent under the null hypothesis. For example, under the null hypothesis if an upward trend was apparent either before or after the change, the assumption was made that an upward trend existed over the whole period being analysed.

This null hypothesis was tested for all of the brigades, and in those brigades where it was found to be false the reasons why a change in trend occurred had to be examined, making it difficult to assess whether the change in station siting had any effect on attendance times.

In those brigades where the null hypothesis held, the effect of the change in station siting was measured by determining whether the position of the trend line after the change had shifted significantly from the position it would have occupied if it had been continuous over the whole period. The variation about the trend line before and after the change have also been compared. (See Table 1).

There are several relevant factors that could affect attendance times in a brigade area:-

(i) A changing traffic situation (e.g. a slowing up in the flow of traffic) - this is most likely to be indicated by the presence of a trend in attendance times.

(ii) A change in the distribution of fires. It may be that housing developments on fringe areas of brigades could lead to increased attendance times. This factor (which would be reflected by the presence of a trend in attendance times) is not so likely to be as important as (i).

(iii) Changes in station siting and "turn-out" facilities. This would be reflected by a shift in the trend line at the time of the change.

Brigade A

The brigade had been operating from an adapted garage which was considered to be inefficient. The building was replaced by a modern purpose-built station on 9th March 1961. As in many other County Boroughs the brigade had to face worsening traffic conditions.

The null hypothesis (that the slope of the trend line of attendance times after the change in station does not differ from that before the change) holds. Unless the assumption, that there was a "settling-in" period of 9 months, can also be made there would appear to have been no significant improvement in attendance times. If, however, this assumption is correct the change of station would appear to have had a beneficial effect on attendance times (see Fig. 1).

As the variation about the trend in mean attendance times remains unaltered if the assumption, (that a "settling-in" period occurred) is made, then the assumption has to some extent been supported.

Brigade B

Amongst the fifteen stations from which the brigade operated, there existed one which had started as an emergency wartime station, forming part of a privately owned petrol station. It was decided to build a replacement station nearby with improved turn-out facilities and easier road access. This station was brought into operational use on 2nd October 1959.

No trend in attendance times appears to have existed during the period analysed, and therefore the null hypothesis holds (see Fig. 2).

The change to the new station has brought about a marked decrease in the mean attendance times to fires in the Brigade area and a decrease in the variation about the mean attendance times. There has therefore been a considerable reduction in the number of occasions on which the attendance time was greater than 4.5 minutes.

Brigade C

The brigade has four fire stations from which to provide fire cover over the County Borough area. On the 1st April 1960 a new station was opened, replacing another which ceased to be operational on the same date.

An upward trend in attendance times is evident, and the null hypothesis was found to hold (Fig. 3). There appears to have been an improvement in attendance times as a result of the change of station, but the variation about the trend in mean attendance times has not altered significantly. Attendance times to the majority of fires served by the new station would appear to have been faster than would have been the case if these fires had been served from the old station.

Brigade D

The brigade had been operating from two fire stations providing cover to a small County Borough. One of these was a war-time station which was replaced by a new station on a different site. The new station was officially opened on 18th April 1957.

Throughout the 5-year period examined in the analysis there was an upward trend in attendance times (Fig. 4). The null hypothesis was found to hold, but no improvement in attendance times occurred as a result of the change of stations. It appears, however, that the variation about the trend in attendance times decreased, which suggests that both the number of low attendance times and the number of high attendance times decreased simultaneously.

Brigade E

The brigade operated from six stations. The site of a temporary war-time station was required by a theological college, and the station was closed on the 25th March 1960. The brigade operated from five stations until a new station became operational on 5th May 1960.

The null hypothesis holds since there was no significant trend in attendance times over the five-year period examined (Fig. 5). There has not, however, been any significant change in attendance times as a result of the change in site. Neither the mean, nor the variation about the mean, have altered to a significant extent.

Brigade F

This brigade had been operating from three fire stations, providing cover to a medium sized, mainly residential, County Borough. Part of the brigade area was poorly served since it was at one time thinly populated. However, the population had been increasing fast, as had the industrial risk, so the number of stations was increased to four. The additional station was opened in the recently developed area on 10th September 1960. (This type of change does not occur often, most changes being simple replacements for older stations).

No trend in attendance times was evident over the 6-year period, and therefore the null hypothesis holds. A marked improvement in attendance times occurred, as can be seen from Fig. 6. The variation in attendance times was found not to have altered, suggesting that most, probably all, of the area served by the new station enjoyed better fire cover as a result of the change.

Brigade G

The brigade, serving a small, somewhat hilly County Borough, operated from one fire station. On 3rd March 1961 the station was moved to a more accessible site about 400 metres away from the previous site.

There was no trend in attendance times during the 3 years prior to the change of station site, but during the 3-year period after the change a marked downward trend set in (Fig. 7). The null hypothesis, therefore, fails. The change from no trend to a downward trend in attendance times appears to have set in approximately 9 months after the change of station site (since this is the point at which the trend lines meet).

The advent of a downward trend in attendance times may be due to a faster traffic flow in the town, a ring road having been brought into use. It appears unlikely that the change in station site, per se, had any effect on attendance times.

Brigade H

This brigade, covering a large County Borough, provided cover from five fire stations. On the 4th June 1959 one of these occupied a new site, the old building ceasing to be operational from that date.

As with brigade G there was no apparent trend in attendance times in the 3 years investigated prior to the change of station site, while during the 3-year period after the change a marked downward trend set in. (Fig. 8).

In this County Borough the change from no trend to a downward trend in attendance times appears to have set in approximately 12 months after the change of station site, suggesting that the change of station site, itself, had no effect on attendance times.   It is possible, however, that the downward trend in attendance times actually set in approximately 12 months prior to the change of station site. If this did, in fact, occur then the change of site would appear to have had a detrimental effect on attendance times.

Brigade J

This is a fairly large brigade area, providing fire cover to two County Boroughs separated by a river across which access is somewhat limited.   The brigade had five full time stations, three in one County Borough and two in the other.   These latter two were replaced by one station, more centrally situated. The change was made on 16th February 1961.

The null hypothesis was found to hold, there being an upward trend in attendance times throughout the 6-year period investigated. (Fig. 9).   No significant improvement in mean attendance times appears to have taken place as a result of the change in station siting, but, somewhat surprisingly, the variation about the trend in attendance times appears to be less after the change. This implies that the frequency with which high attendance times occurred was markedly reduced.

Brigade K

This brigade provides fire cover to a small County Borough divided by a river, across which there is only one bridge.   It had two fire stations, both on the same side of the river, one of which was a temporary war-time station.   This was replaced by a modern structure on the other side of the river which was officially opened on 4th February 1960.   This brigade is unusual in that approximately 15 per cent of the fires it attends occur outside the County Borough boundaries.

The null hypothesis did not hold, implying that the trend in attendance times after the change differed from that before the change.   Unfortunately during the period after the change the town suffered exceptionally heavy traffic owing to the building of a very large steelworks on the perimeter of the town;   the traffic density rose to a peak in February 1964, four years after the change in station siting.

An inspection of the graph (Fig. 10) showing the history of brigade K attendance times over this period suggests that the trend in the post-change period was not linear, mean attendance times increasing more sharply during the first 15 months or so, than later in the period.

With the insertion of a curve rather than a straight line to describe the trend in attendance times in the post-change period, there is a suggestion that the change in station site had the beneficial effect on attendance times that was confidently expected of it.   It is not, however, possible to be categorical about this from the results of this study.

Brigade L

Brigade L had three fire stations from which to provide fire cover to a large County Borough which is surrounded partly by built-up areas served by adjacent County Authorities.   It had also to provide fire cover to a new housing

estate situated on the opposite side of a river crossable at only two points. (A third road bridge has a strict weight limit). A new station was brought into operation on 1st September 1960 providing improved coverage to the new housing estate. Simultaneously, one of the old stations closed down.

The null hypothesis was found to hold, there being a significant upward trend in attendance times throughout the six year period under investigation. The provision of an additional station appears to have brought about an improvement in attendance times. The number of high attendance times in particular appears to have been greatly reduced; this being reflected by a significant decrease in the variation about the trend in attendance times.

Brigade M

Brigade M covers a small County Borough with three full-time stations. One of the stations was a temporary war-time station. This was replaced by a more modern structure which became effective on the 23rd April, 1959.

The null hypothesis was found to hold since there was no apparent trend in attendance times over the six year period investigated, as can be seen from Fig. 12. The mean attendance time did not alter significantly, but there was a significant decrease in the variation in attendance times after the change of station. Both long and short attendance times appear to have become less frequent, implying that it has become easier to reach outlying districts, but that near-by locations are not quite so accessible.

Brigade N

The brigade operates from one station and provides fire cover to a small County Borough. Slum clearance and re-development schemes necessitated a re-siting of the station. The new station, which is on a main road on the outskirts of the town, has been operational since 24th April 1962.

The null hypothesis holds since an upward trend in attendance times is discernable for both the three years before, and the two years after the re-siting of the station (Fig. 13). There appears to have been an increase in attendance times as a result of the change of station site, while the variation about the trend in attendance times appears to have remained unaltered. In other words, low attendance times have become less frequent while high attendance times have become more frequent as a result of the re-siting.

Brigade P

This brigade provides fire cover to a small County Borough and it was operating from one fire station. The County Borough is highly industrialized and is surrounded by industrial county areas. A new station was opened on 24th August, 1959, with the old station continuing to operate as a sub-station (it is nearer to high risk areas).

There was no perceptible trend in attendance times during the 6-year period covered by this investigation, so the null hypothesis holds. There was no significant change in mean attendance times due to the addition of a station, nor did the variation in attendance times alter significantly. The addition of a station by this brigade, therefore, appears to have had no effect on attendance times.

Brigade Q

This brigade, operating from one fire station, provided fire cover to a small but highly industrialized County Borough with similar adjacent administrative areas. A new station was brought into operation on 29th July 1959, when the old Headquarters ceased to function.

The null hypothesis holds since no trend in attendance times is apparent over the 6-year period investigated. The mean attendance time for the three year period after the change in station is significantly higher than the mean attendance time for the three year period prior to the change. Simultaneously, the variation about the mean attendance time decreased significantly.

The change in station has had the effect of increasing attendance times, while providing greater uniformity of cover. On average the time taken to reach fires has significantly increased, with low attendance times in particular occurring relatively infrequently since the new station came into operation.

Brigade R

The brigade serves a small County Borough and operated from one fire station. This was replaced by a new building which became operational on 3rd November 1959.

There was an upward trend in attendance times during the 6 year period investigated, and the null hypothesis, therefore, holds.

The change of station does not appear to have appreciably reduced the average attendance time, but there does appear to have been a reduction in the number of long attendance times as a result of the change, (since there appears to have been a decrease in the variation about the trend in mean attendance times).

Discussion and Conclusions

The average time taken to attend fires in any particular brigade area depends on the number of stations providing fire cover, where the stations are sited, and the excellence of the turn out facilities from the stations.

Sixteen brigades in which changes in station sites were made between 1957 and 1962 have been analysed to assess the effect of the change upon attendance times. A summary of the results is given in Table 1; details are shown in Table 2.

In thirteen of the brigades a new station replaced one of the existing stations. In two of the brigades an additional station was opened, and there was one brigade in which one station replaced two of the existing stations.

No satisfactory conclusions could be drawn from three of the brigades as extraneous circumstances (such as affect traffic flow) appear to have altered the trend in attendance times during the period examined. In each of of these the change was a simple replacement.

In the other ten brigades where the change was the replacement of one station for another, seven showed an improvement in attendance times, two showed a deterioration in attendance times, while the change had no apparent effect on the attendance times of the last brigade. Of the seven brigades in which an improvement was observed, four showed an improvement in mean attendance times together with a reduction in the number of high attendance times in two of the brigade areas, while three improved by reducing the frequency of high attendance times

only. In both of the brigades in which a deterioration in attendance times was observed the deterioration affected the whole range of attendance times, but the deterioration was marked by a more than proportional reduction in low attendance times in one of the two brigades.

Of the two brigades in which an additional station was opened, one showed an overall improvement in attendance times, but in the other no significant change in attendance times was observed. Since attendance times are expected to be lower when an additional station is brought into operation to cover the same brigade area, the choice of site for the additional station appears to have been poor. The site of the original station appears to be superior to that of the additional station in terms of attendance times.

In the only brigade where one station replaced two stations the number of high attendance times appears to have been reduced. On the assumption that the fire cover commitments of the brigade remained the same it can be seen that the previous stations were very much on the fringe of the brigade area in terms of fire and were having to travel towards the centre in the majority of calls. The new station has been placed in the centre, nearer to where the majority of calls are likely to come. Turn-out facilities may, of course, be better.

Changes in station siting have, therefore, been found to improve attendance times in the majority of cases, but it is also apparent that a change can result in a deterioration in attendance times. On the assumption that a major aim of the changes was to reduce attendance times (if possible), the ratio of decisions, good, indifferent, and poor has been found to be 9:1:3.

In general, the more stations there are serving a given brigade area the better is the fire-cover expected to be in terms of the average time taken to get to a fire. That this is not always so can be seen from the case of brigade J in this study. The siting of stations must also reflect the relative frequency of fires in the various constituents of the brigade area. For example, if a station must be sited to serve two areas, A and B, a mile apart, A having 3x fires to B's x fires per year, then to minimize mean attendance time over a long period the site should be a quarter of a mile from A, and three-quarters of a mile from B.

The likely size and expense of fires should, of course, also be taken into account when making a realistic appraisal of the situation. The difference in the ultimate spread of fires because of the final minute taken to attend the fires is also pertinent when deciding whether to site the station nearer to area A than area B. The cost of the spread of all fires in a year in area A because of the last minute of attendance time should be equal to the cost of spread due to the last minute of attendance time of all the fires in area B, over the same period. If these costs are not equal fire losses would be reduced by siting the station closer to the area where the costs were higher as a consequence of the last minute of attendance time. Possible loss of life in both areas should also be taken into account.

The same principles apply when there is more than one station to site, the solution being obtained through a series of iterations.

Attendance times alone, however, are not the only criterion by which a good site for a fire station is judged. Minimum dimensions are required in the site for the station. This is essential both for the efficient

training and mobilization of the brigade, and for the housing of all necessary appliances. (The efficient fighting of a large fire may be more vital than a quick turn out to a lot of small fires). It is also essential that appliances on call should be able to enter the highway with the minimum delay, without at the same time causing a disruption in the traffic flow, so that the appliances themselves are held up by a jam resulting from their own entry onto the thoroughfare. Another factor which has to be considered is the speed of traffic flow along the alternative roads onto which the appliances must turn after emerging from the station, since it is not the distance from the fire that matters, but how many minutes it takes to travel there, (observing all the Highway Code Regulations on the journey). A gloomy, out-of-date, building on a good site may, also, not be preferable to a modern, well equipped station on only a moderate site, as the performance of the brigade may thereby be affected.

Optimum efficiency in any brigade can not, however, be achieved unless the costs of brigade premises, manpower, appliances, equipment, training etc, are known and are weighed against the losses due to fire. For example, if the cost of moving to a new station is £5 000 a month, and this move would only result in an average reduction of only £2 000 a month in fire losses then at least from the standpoint of reducing financial loss the move should not be made since it would cost the community an additional £3 000 a month on average. A complicating factor of course is the function of the brigade to help save life, but even in this function it is feasible for efficiency to be assessed in a quantitative manner. Any change that is contemplated should in principle be examined in accordance with the criterion that the cost of the change will be offset, or more than offset by the resultant reduction in fire losses or the resultant expected improvement in saving of life. It would be helpful in achieving this end if reports of fires attended by the fire brigades gave an estimate of the cost of the damage due to the fire and its extinction. In the context it should be stressed that a very approximate estimate is better than none at all. An accurate assessment of the distribution of the fire losses can be made if sufficient data are collected, even with a high margin of error in each of the estimates.

TABLE 1

SUMMARY OF RESULTS OBTAINED

(AT 90 PER CENT CONFIDENCE LEVEL)

Brigade	Type of change[1]	Trend in attendance times	Change in extrapolated mean	Change in variation about trend	Type of analysis[2]
A	O	Upward	Decrease	None	*
B	O	None	Decrease	Decrease	S
C	O	Upward	Decrease (at 89 per cent C.L)	None	*
D	O	Upward	None	Decrease	*
E	O	None	None	None	ST
F	+ 1	None	Decrease	None	S
G	O	Changeable	–	–	S
H	O	Changeable	–	–	ST
J	2 = 1	Upward	None	Decrease	ST
K	O	Changeable	–	–	S
L	O	Upward	Decrease (at 88 per cent C.L)	Decrease	ST
M	O	None	None	Decrease	ST
N	O	Upward	Increase	None	S
P	+ 1	None	None	None	S
Q	O	None	Increase	Decrease	S
R	O	Upward	None	Decrease	*

1   O Simple replacement of one station for another
   + 1 Provision of an additional station
 2 = 1 Replacement of two stations by one

2   * Regressions on monthly mean attendance times
    S Regressions on seasonally corrected monthly mean attendance times
  ST Regressions on transformed, seasonally corrected monthly mean
      attendance times (using square root transformation)

TABLE 2

DETAILS OF CHANGES IN ATTENDANCE TIMES AT TIME OF RESITING

Brigade	Value of estimated mean		Difference between means $(\bar{\bar{x}}_a - \bar{\bar{x}}_b)$ (mins)	Min. value of $\|\bar{\bar{x}}_a - \bar{\bar{x}}_b\|$ required at 90% C.L. for significance	Confidence level that $\bar{\bar{x}}_a \neq \bar{\bar{x}}_b$
	Before change $\bar{\bar{x}}_b$ (mins)	After change $\bar{\bar{x}}_a$ (mins)			
A	5.77	4.51	− 1.26	0.67	99.7%
B	4.47	4.26	− 0.21	0.09	❭99.9%
C	3.12	2.77	− 0.35(*)	0.35(*)	89%
D	3.83	3.74	− 0.09	0.45	62%
E	3.98	3.88	− 0.10	0.13	80%
F	4.35	4.05	− 0.30	0.16	99.8%
G	–	–	–	–	–
H	–	–	–	–	–
J	3.51	3.39	− 0.12	0.16	78.5%
K	–	–	–	–	–
L	3.87	3.61	− 0.26	0.27	88%
M	3.78	3.62	− 0.16	0.20	81%
N	3.24	3.56	+ 0.34	0.21	98%
P	3.92	4.11	+ 0.19	0.23	80%
Q	3.10	3.73	+ 0.63	0.16	❭99.9%
R	2.76	2.52	− 0.24	0.33	76%

(*) Due to rounding errors these two quantities appear equal: in fact the first number is less than the second.

Brigade B - Calculation

Number the months before the change x_{iB} (i.e. 1, 2, ... 24)

Number the months after the change x_{jA} (i.e. 1, 2, ... 36)

Let the monthly mean attendance times (in this case they are seasonally corrected) be Y_{iB} and Y_{jA}

Calculation of seasonal corrections

The trend line is calculated by a "moving average" technique[*] in which the means were averaged over successive periods of twelve months to determine a "trend value" for each month. The deviations of the monthly means from their trend values are shown below (minutes):-

Year	Month					
	1	2	3	4	5	6
1						
2	+ 0.303	- 0.360	+ 0.227	+ 0.288	+ 0.464	- 0.197
3	- 0.057	+ 0.087	- 0.016	+ 0.306	+ 0.087	+ 0.229
4	+ 0.085	+ 0.051	- 0.088	+ 0.238	+ 0.130	- 0.073
5	- 0.077	- 0.151	+ 0.565	+ 0.381	+ 0.063	+ 0.255
Total	+ 0.254	- 0.273	+ 0.688	+ 1.213	+ 0.744	+ 0.214

(1)

Year	Month					
	7	8	9	10	11	12
1	- 0.120	- 0.027	- 0.255	- 0.155	- 0.039	- 0.378
2	+ 0.219	- 0.282	+ 0.255	- 0.230	- 0.248	- 0.205
3	- 0.029	- 0.622	- 0.307	- 0.095	- 0.108	- 0.101
4	+ 0.036	+ 0.153	- 0.142	- 0.159	- 0.377	- 0.074
5						
Total	+ 0.106	- 0.178	- 0.449	- 0.639	- 0.772	- 0.758

(1)

(*) Method described in detail in
MOUNSEY, J. Introduction to Statistical Calculations Chapter II.
English University Press. First Published 1952.

To average over the four complete years (the first six months and last six months over the whole five year period cannot be used for calculation of deviations since it is not possible to determine a trend value) these quantities (1) were divided by 4.

Month					
1	2	3	4	5	6
+ 0.064	- 0.068	+ 0.172	+ 0.303	+ 0.186	+ 0.053

Month					
7	8	9	10	11	12
+ 0.027	- 0.045	- 0.112	- 0.160	- 0.193	- 0.190

Applying a zero-izing factor these seasonal corrections become:-

Month					
1	2	3	4	5	6
- 0.061	+ 0.071	- 0.169	- 0.300	- 0.183	- 0.050

Month					
7	8	9	10	11	12
- 0.024	+ 0.048	+ 0.115	+ 0.163	+ 0.196	+ 0.193

These corrections are applied to the monthly mean attendance times over the whole 5 year period

Regression Analysis (Before change)

$$\Sigma x_{iB} = 1 + 2 + \ldots\ldots + 24 = \underline{300} \qquad \Sigma x^2_{iB} = 1^2 + 2^2 + \ldots\ldots + 24^2 = \underline{4900}$$

$$\Sigma y_{iB} = \underline{107.288} \qquad \Sigma y^2_{iB} = \underline{480.839982}$$

$$\Sigma x_{iB} y_{iB} = \underline{1\,334.522}$$

$$Sy^2_{iB} = \Sigma y^2_{iB} - \frac{1}{24}(\Sigma y_{iB})^2 = \underline{1.226860}$$

$$Sx^2_{iB} = \Sigma x^2_{iB} - \frac{1}{24}(\Sigma x_{iB})^2 = \underline{1150.0}$$

$$Sx_{iB}y_{iB} = \Sigma x_{iB}y_{iB} - \frac{1}{24}(\Sigma x_{iB})(\Sigma y_{iB}) = -\underline{6.578}$$

Hence $b_B = \dfrac{Sx_{iB}y_{iB}}{Sx^2_{iB}} = -0.005720$

$\bar{x}_B = \underline{12.5}$ $\bar{y}_B = \underline{4.470}$ (mean attendance time before change)

R_BSS (regression sum of squares)

$$= b_B Sx_{iB}y_{iB} = \underline{0.037626}$$

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Regression $(R_B\text{SS})$	1	0.037626	0.037626
Residual $(Sy^2_{iB} - R_B\text{SS})$	22	1.189234	0.054056
TOTAL (Sy^2_{iB})	23	1.226860	$0.053342(s^2_B)$

The variance ratio $= \dfrac{0.037626}{0.054056} < 1$ and hence the regression is not significant.

Regression Analysis (After change)

$$\Sigma x_{jA} = 1 + 2 + \ldots\ldots + 36 = \underline{666} \quad \Sigma x^2_{jA} = 1^2 + 2^2 = \ldots\ldots + 36^2 = \underline{16206}$$

$$\Sigma y_{jA} = 153.267 \qquad\qquad \Sigma y^2_{jA} = \underline{653.331533}$$

$$\Sigma x_{jA}y_{jA} = \underline{2,836.980}$$

$$Sy^2_{jA} = \Sigma y^2_{jA} - \frac{1}{36}(\Sigma y_{jA})^2 = \underline{0.810053}$$

$$Sx^2_{jA} = \Sigma x^2_{jA} - \frac{1}{36}(\Sigma x_{jA})^2 = \underline{3885.0}$$

$$Sx_{jA}y_{jA} = \Sigma x_{jA}y_{jA} - \frac{1}{36}(\Sigma x_{jA})(\Sigma y_{jA}) = \underline{0.001540}$$

Hence $b_A = \dfrac{Sx_{jA}y_{jA}}{Sx^2_{jA}} \qquad \underline{0.000001}$

$x_A = \underline{18.5} \quad y_A = \underline{4.257}$ (mean attendance time after change)

R_ASS (regression sum of squares)

$$= b_A Sx_{jA}y_{jA} = 0.000000$$

(it cannot be less than 0)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Regression $(R_A SS)$	1	0.000000	0.000000
Residual $(Sy^2_{jA} - R_A SS)$	34	0.810053	0.023825
TOTAL (Sy^2_{jA})	35	0.810053	0.023144 $(\hat{s}^2_A)$

Difference in means before and after the change

Consider the value of

$$\frac{\bar{y}_B - \bar{y}_A}{\sqrt{\dfrac{\hat{s}^2_B}{n_B} + \dfrac{\hat{s}^2_A}{n_A}}}$$

(Here $n_B = 24 \quad n_A = 36$)

This becomes

$$\frac{4.470 - 4.257}{\sqrt{\dfrac{0.053342}{24} - \dfrac{0.023144}{36}}} \quad = \quad 3.98 \quad\quad 1.67$$

(Using t-test, 10 per cent level of significance)

Hence it can be stated with 90 per cent confidence that the mean has reduced.

Difference in variances before and after the change

Variance before change = $\hat{s}^2_B$ = 0.053342 (23 d.f)

Variance after change = $\hat{s}^2_A$ = 0.023144 (35 d.f)

Variance Ratio = $\dfrac{\hat{s}^2_B}{\hat{s}^2_A}$ = $\dfrac{0.053342}{0.023144}$ = $\underline{2.305}$

The $F_{23,35}$ - distribution value at the 10 per cent level of significance is 1.61, hence it can be stated with 90 per cent confidence that there has been a real reduction in variation after the change.
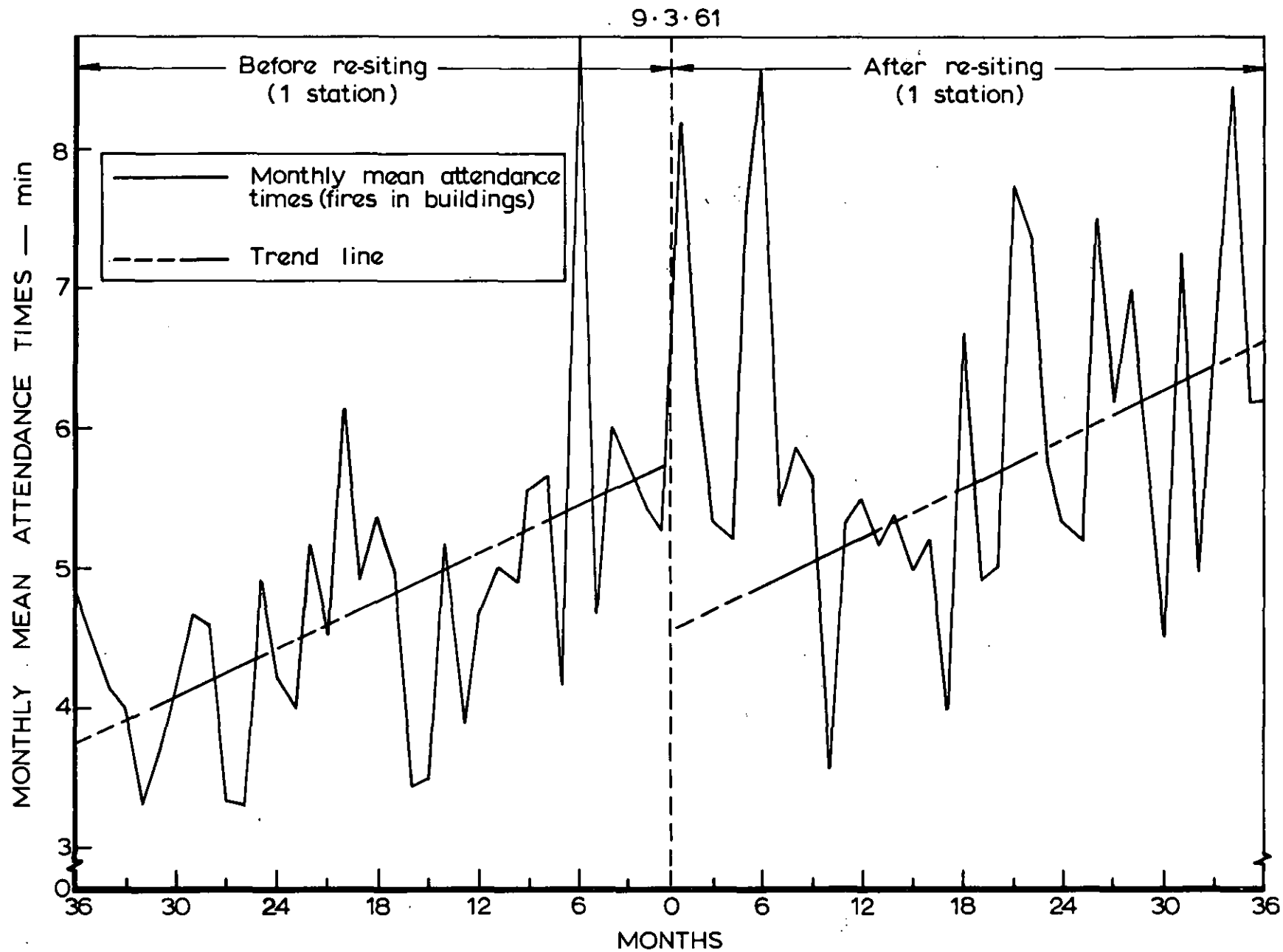
FIG.1.   BRIGADE "A"
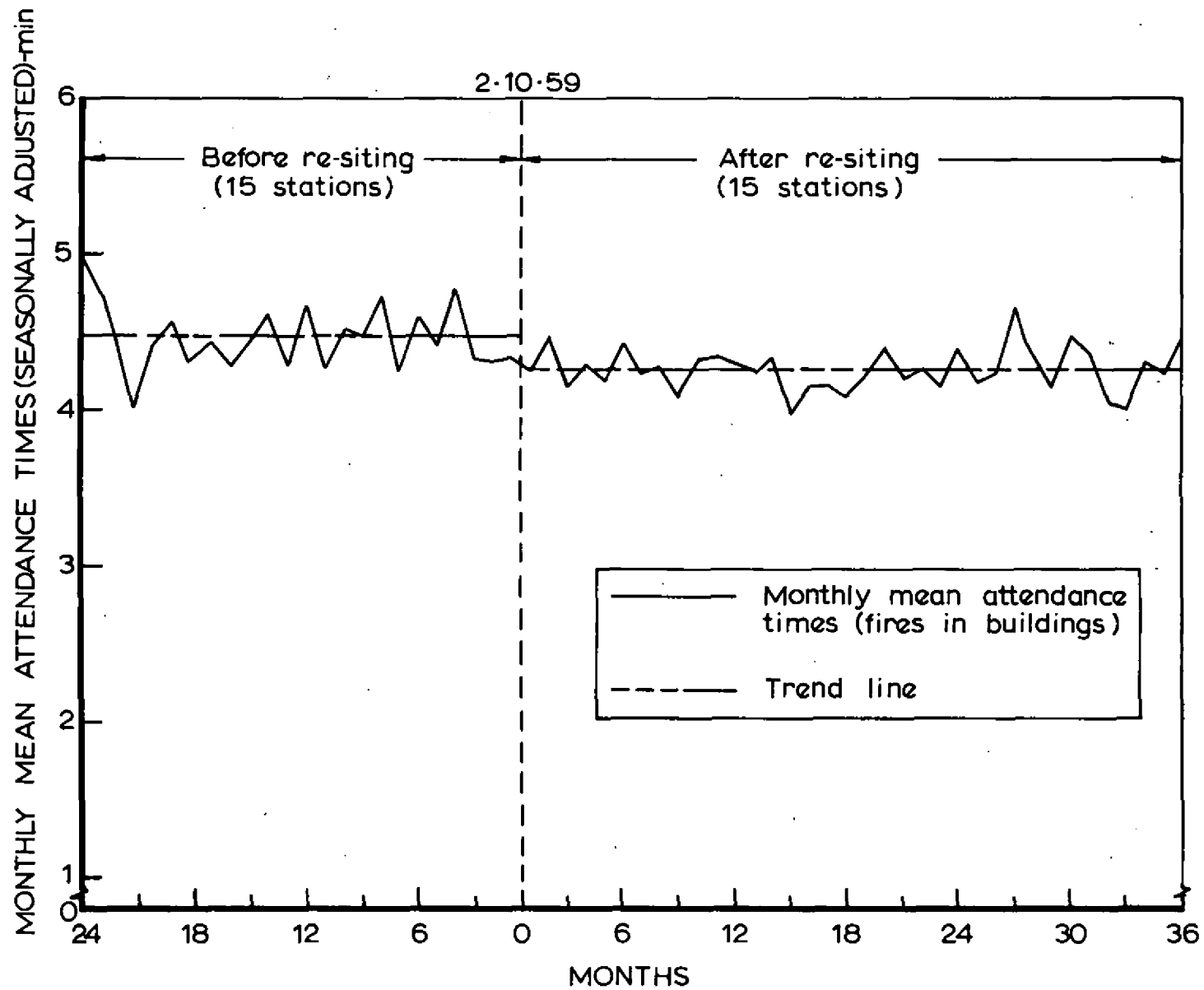
FIG.2. BRIGADE "B"
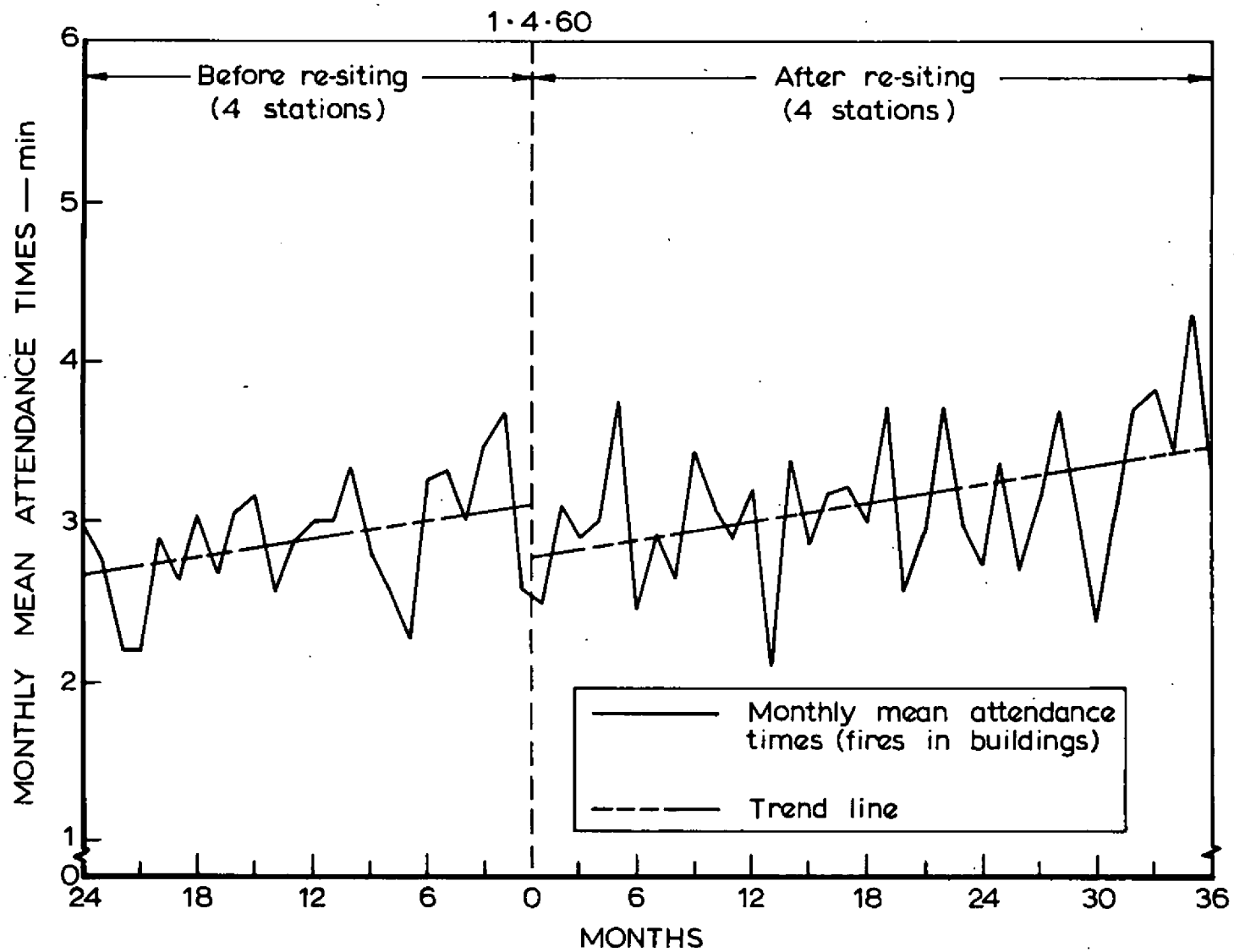
FIG. 3. BRIGADE "C"

FIG.4. BRIGADE "D"

(25·3·60:5·5·60)
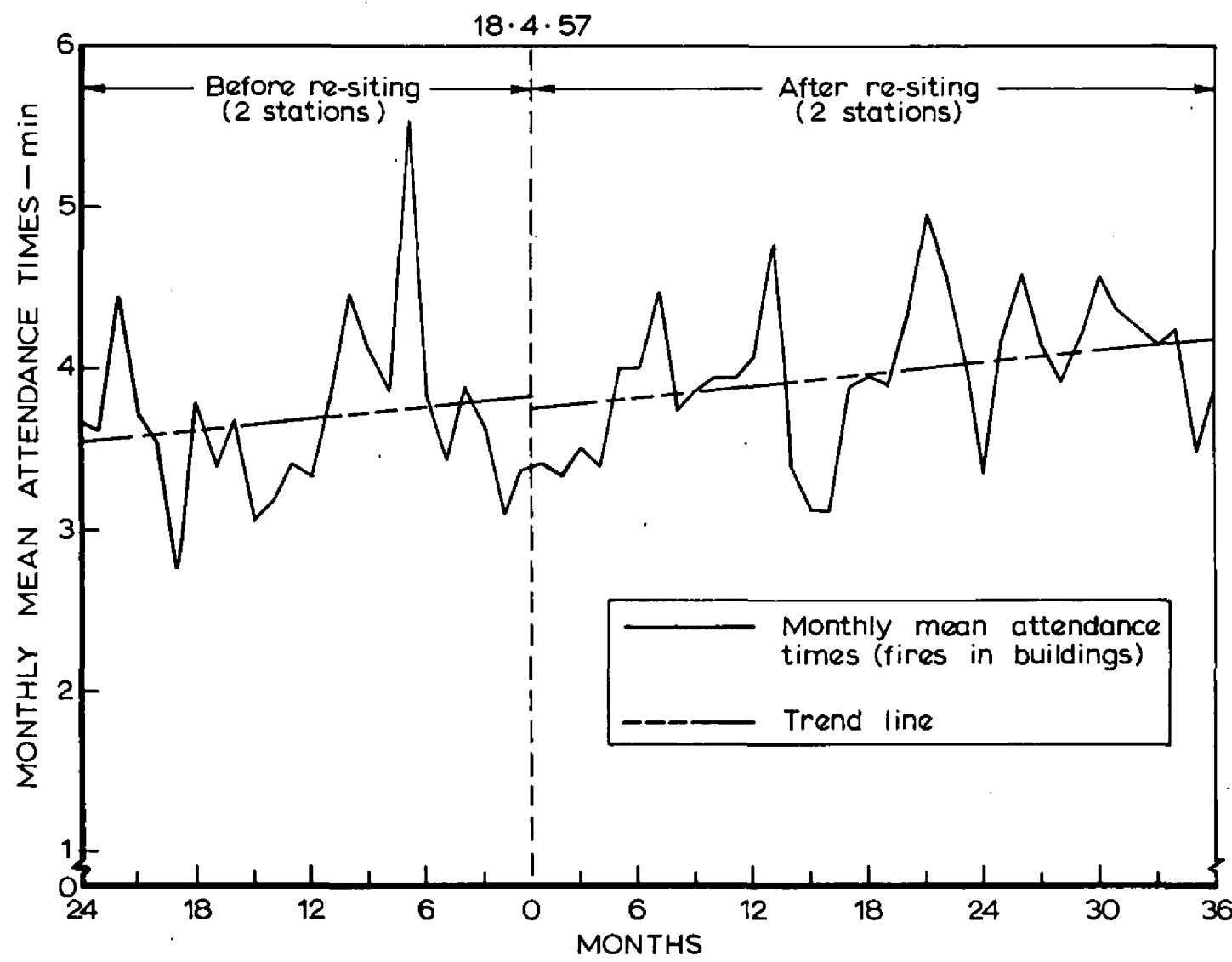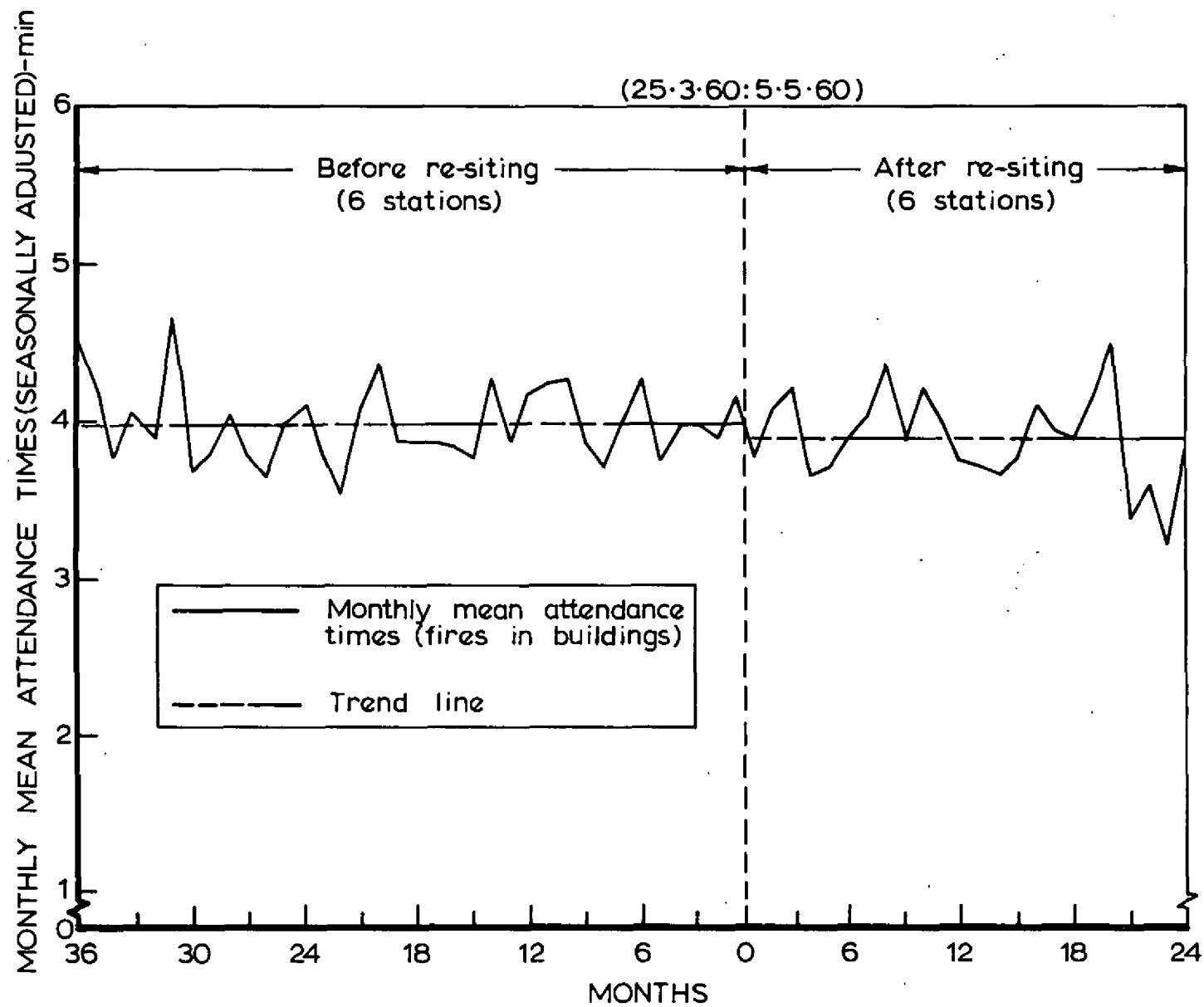
FIG.5. BRIGADE "E"
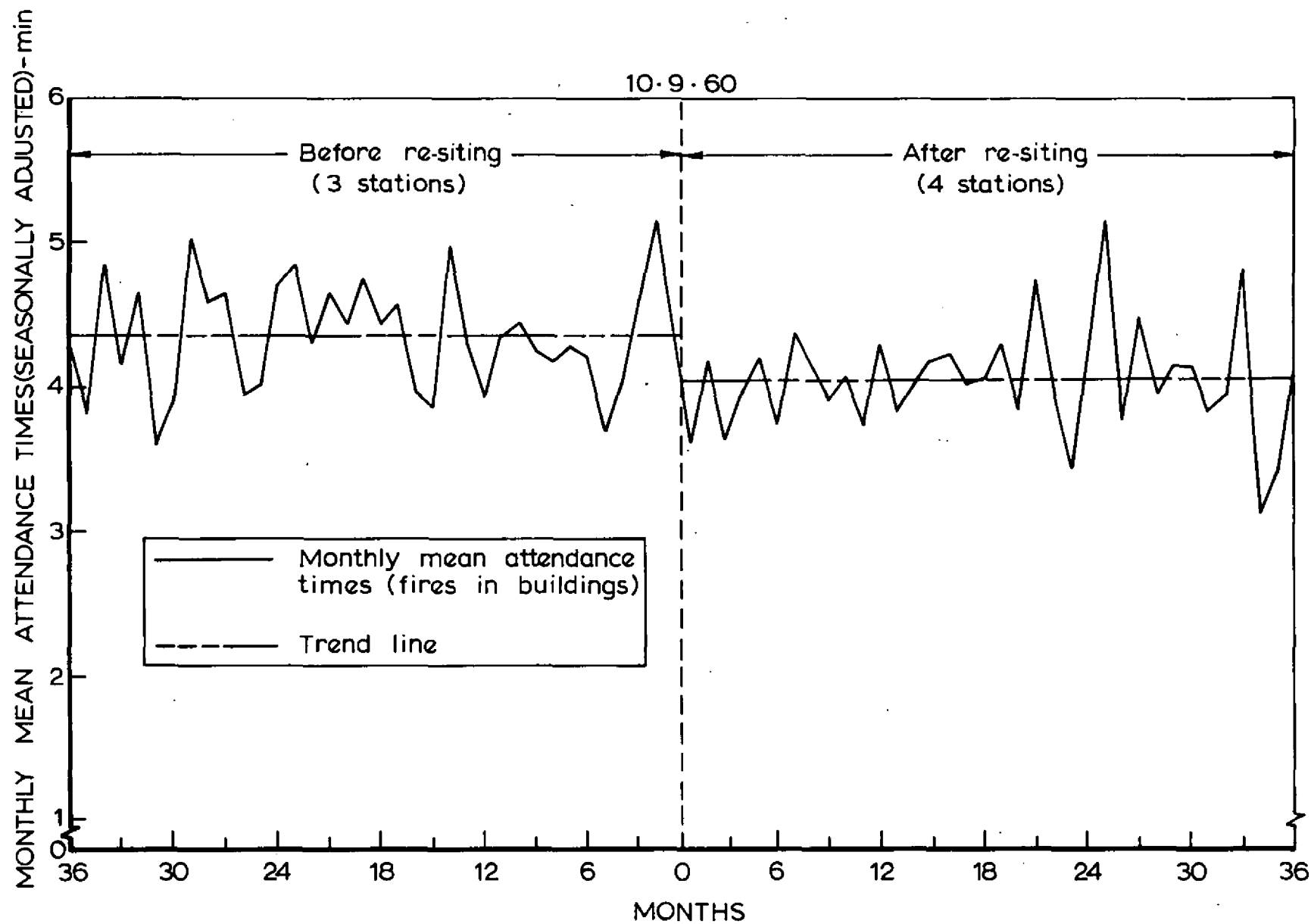
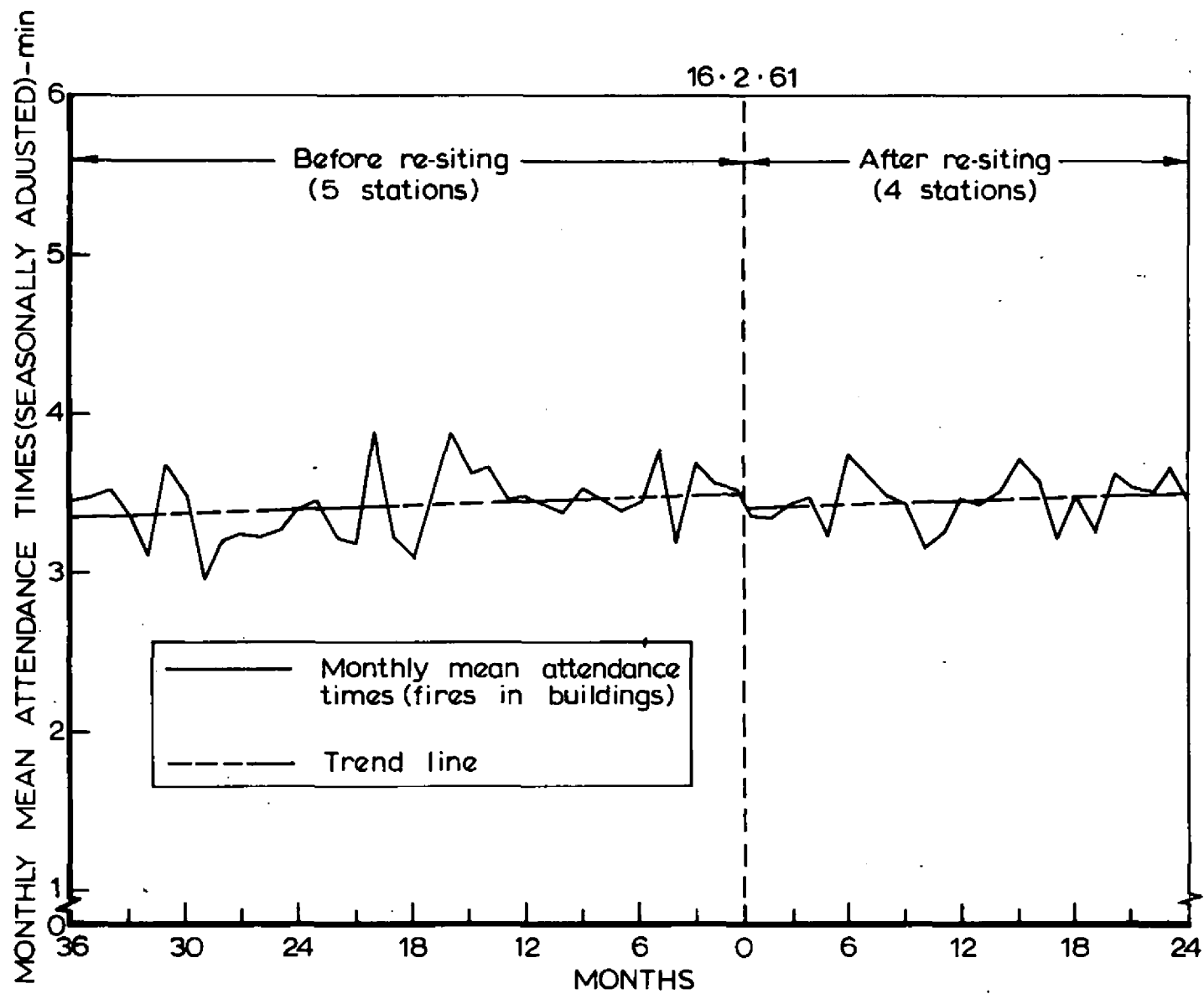FIG.6. BRIGADE "F"
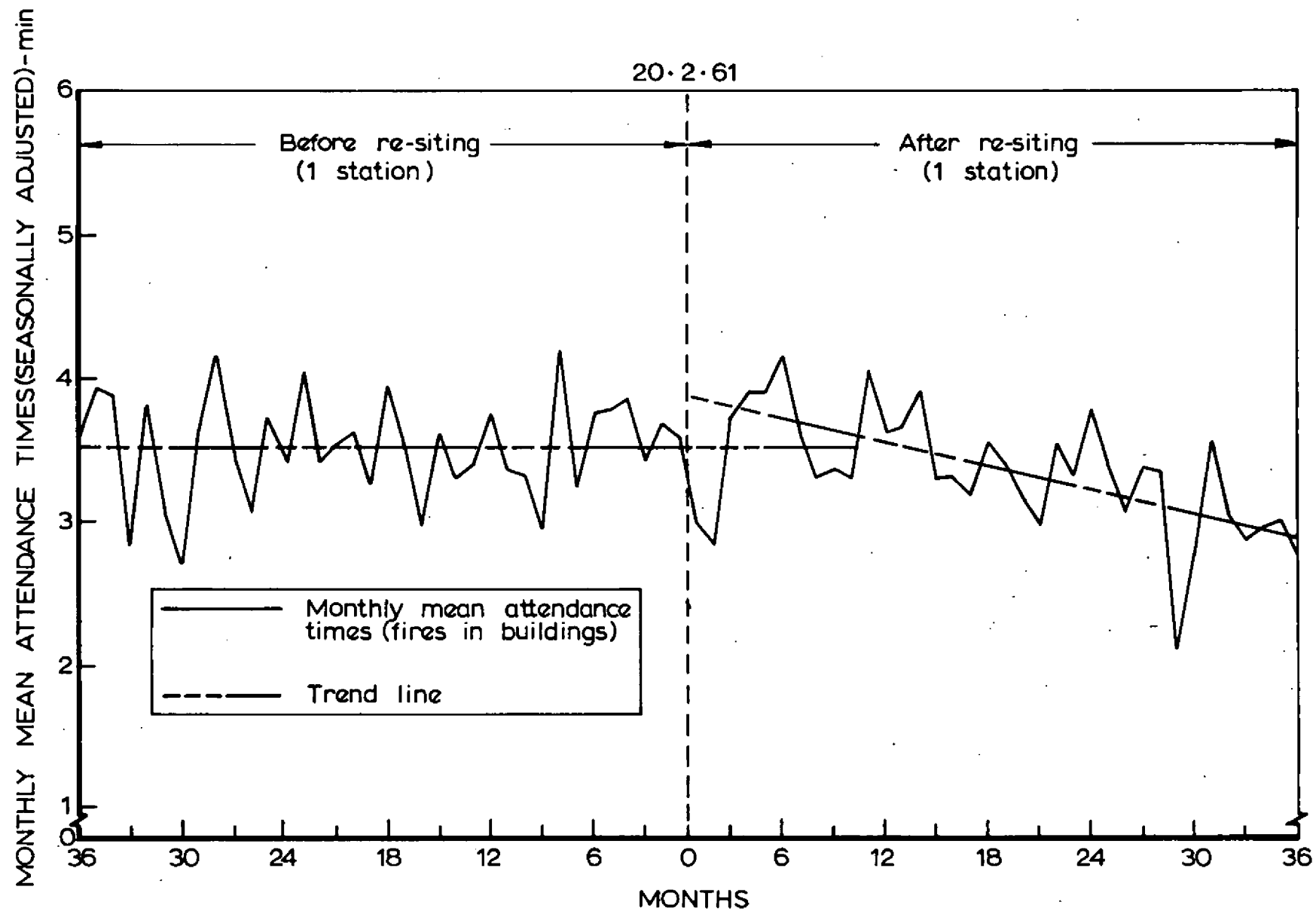
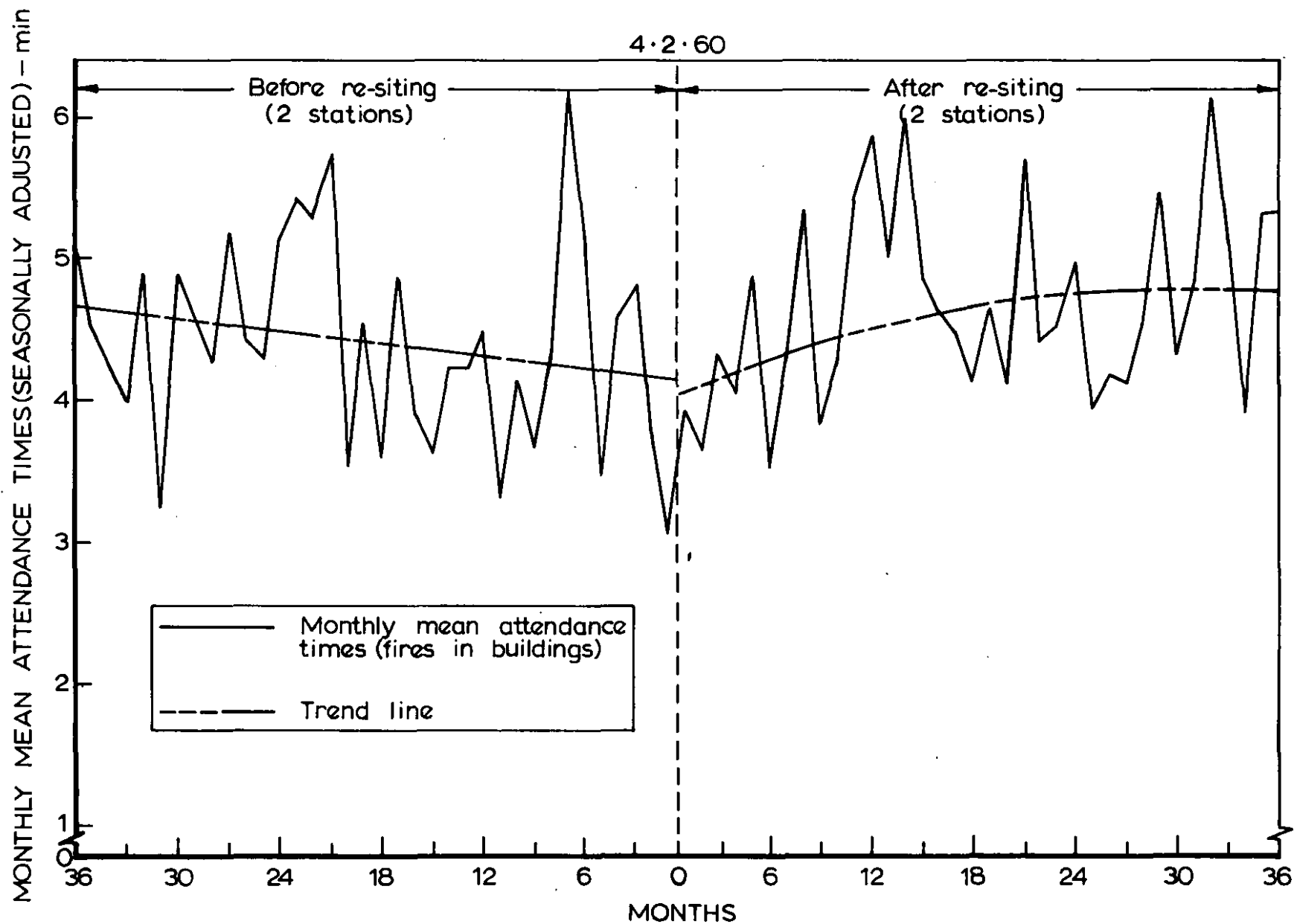FIG.7. BRIGADE "G"
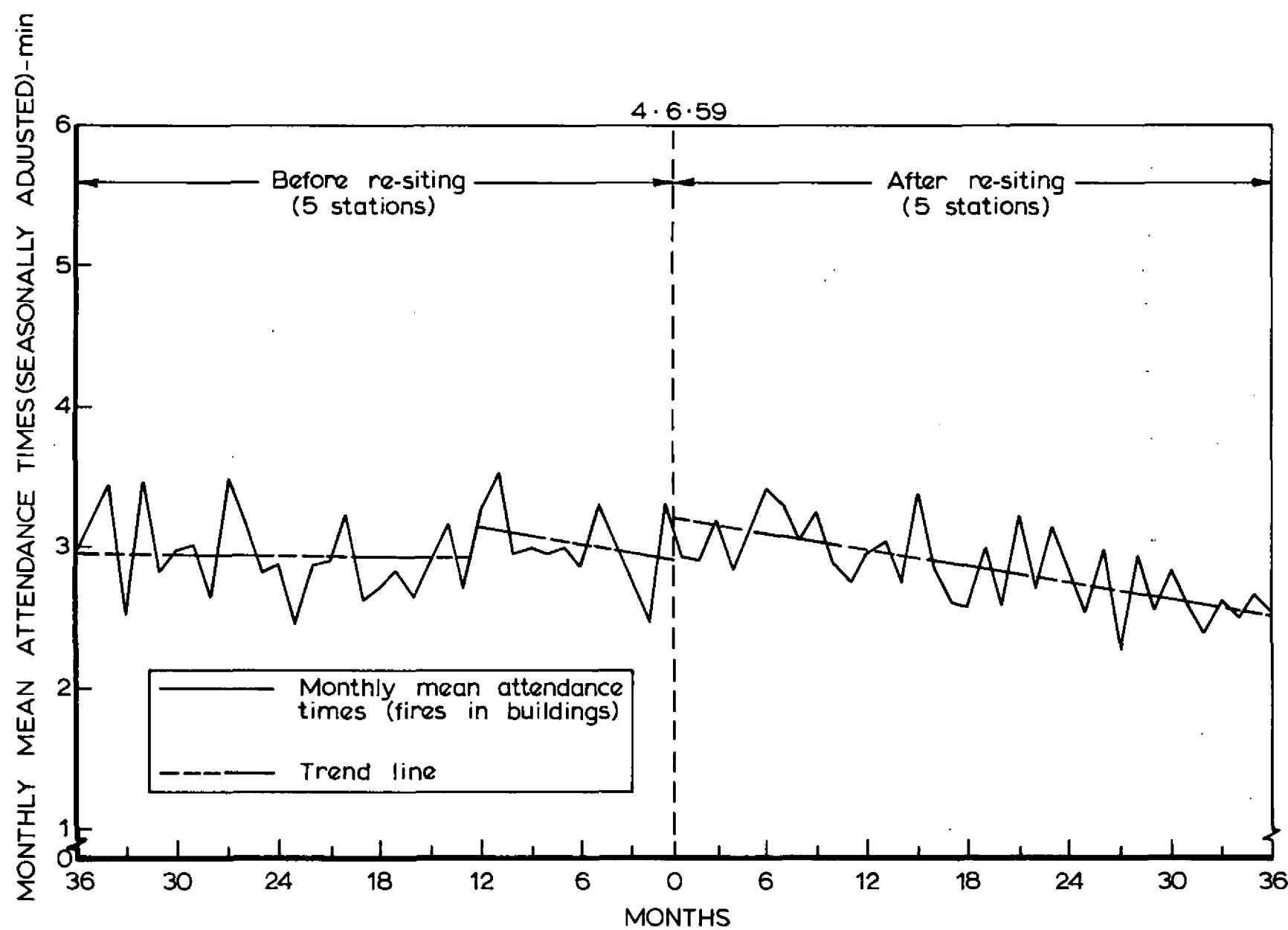
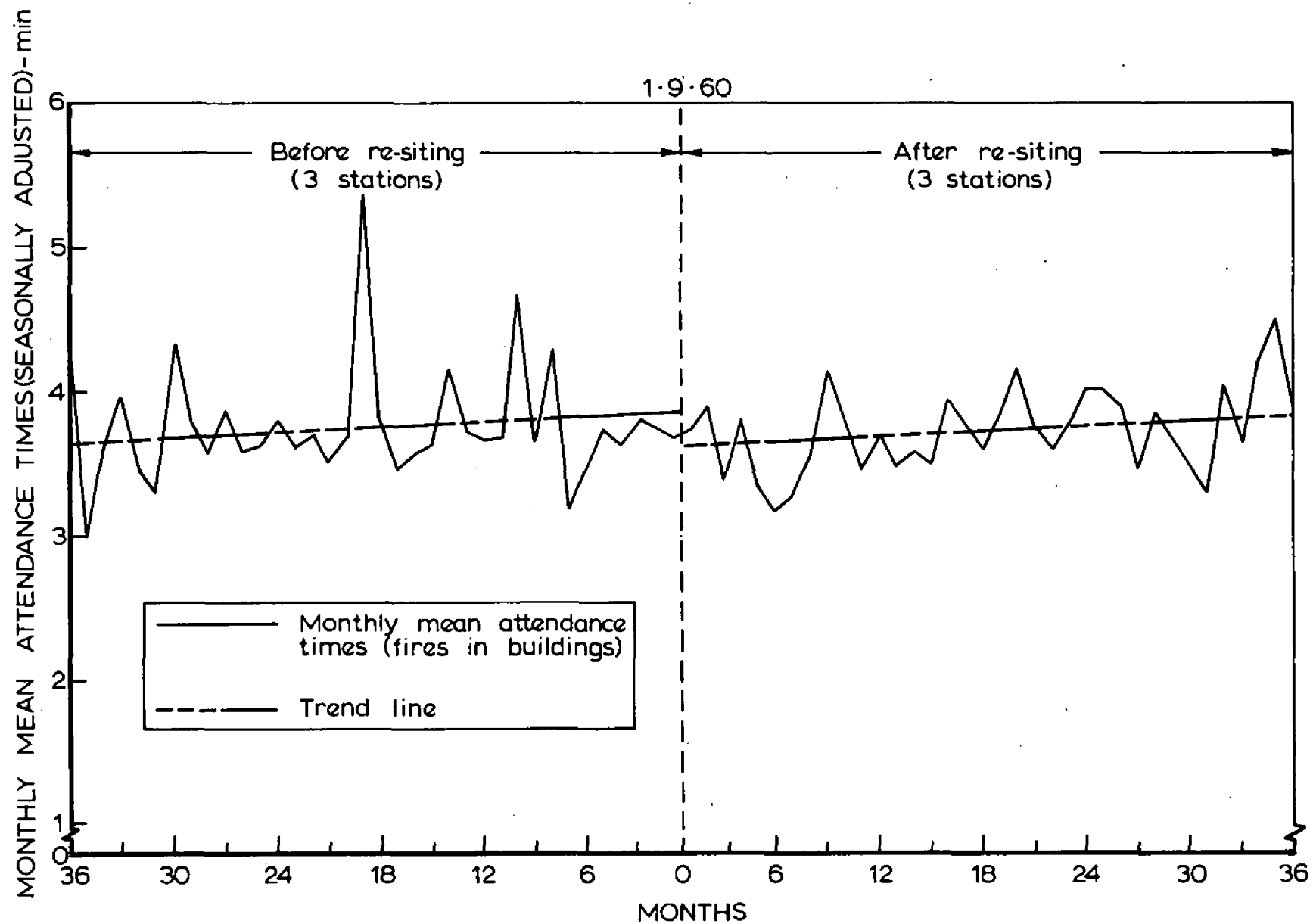FIG. 8. BRIGADE "H"

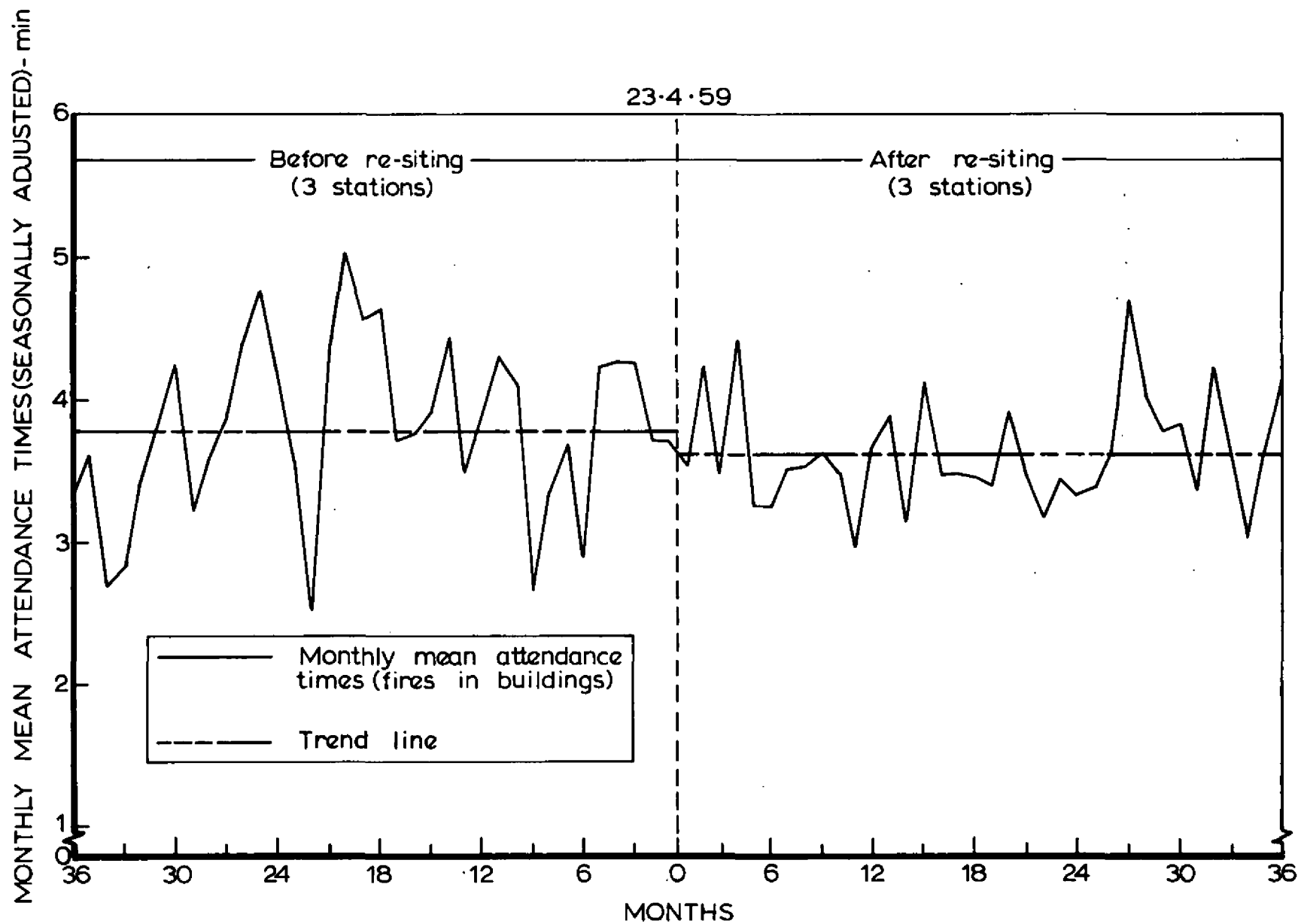FIG. 9. BRIGADE "J"

FIG.10. BRIGADE "K"

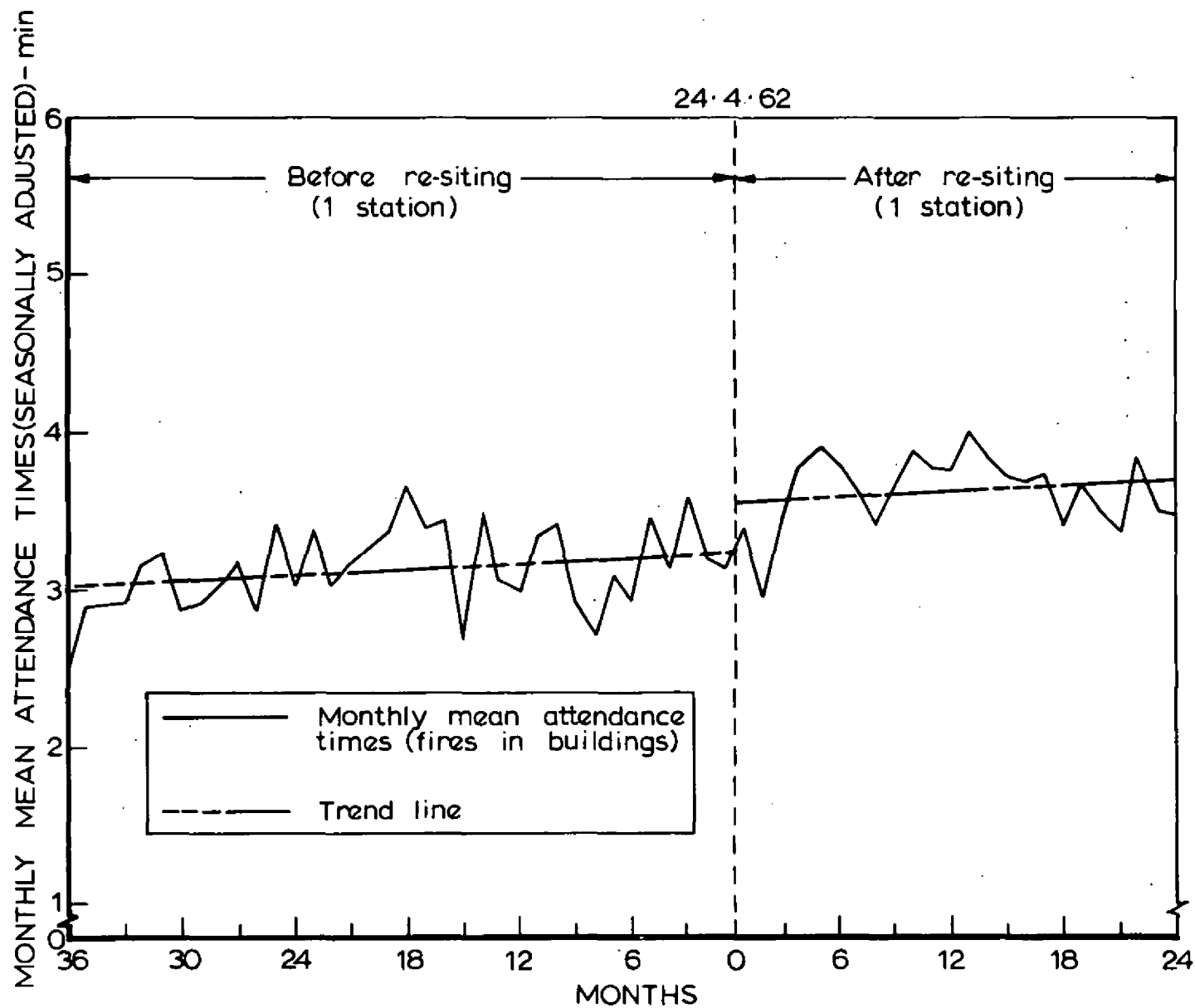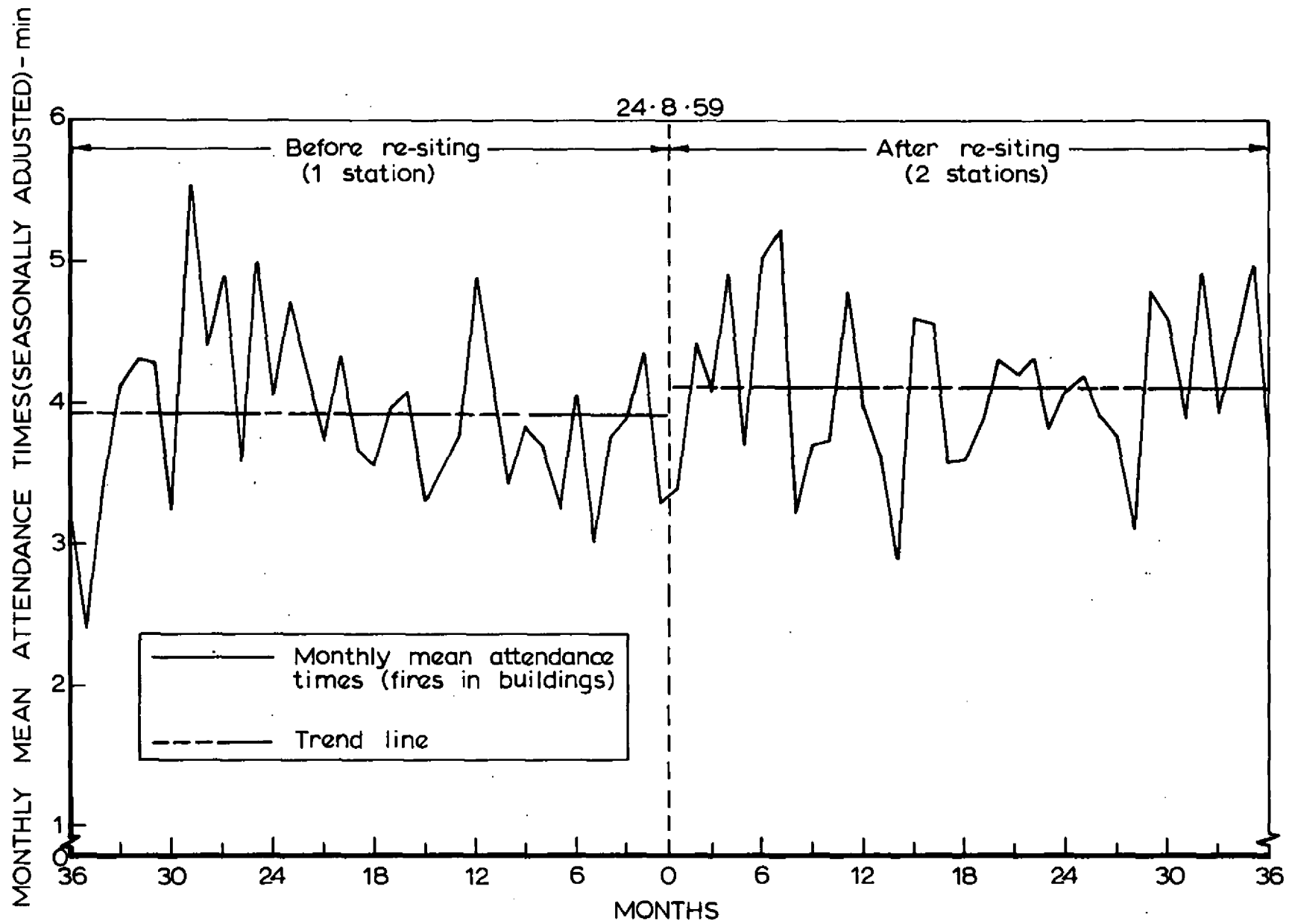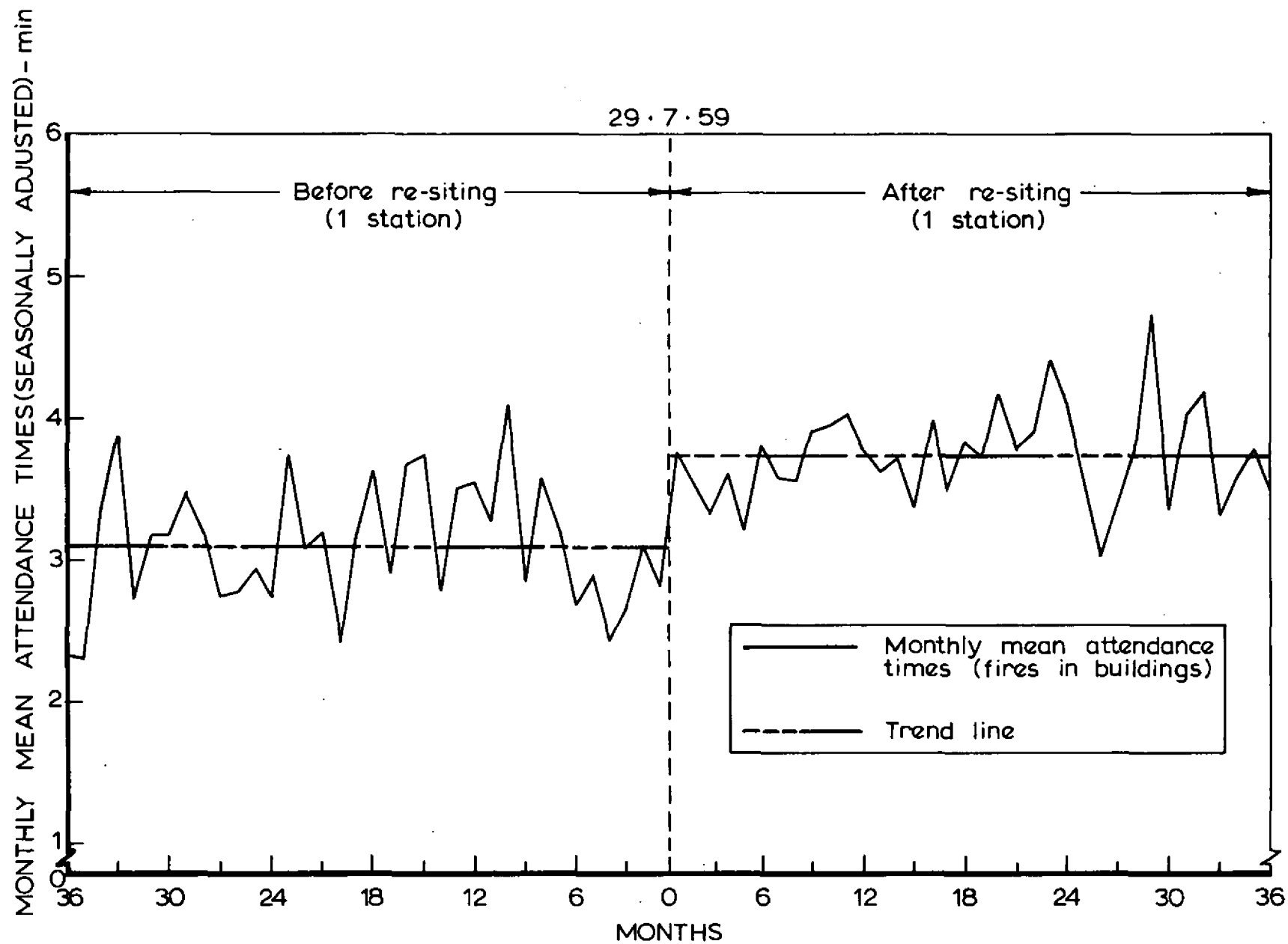FIG. 11. BRIGADE "L"

FIG.12. BRIGADE "M"

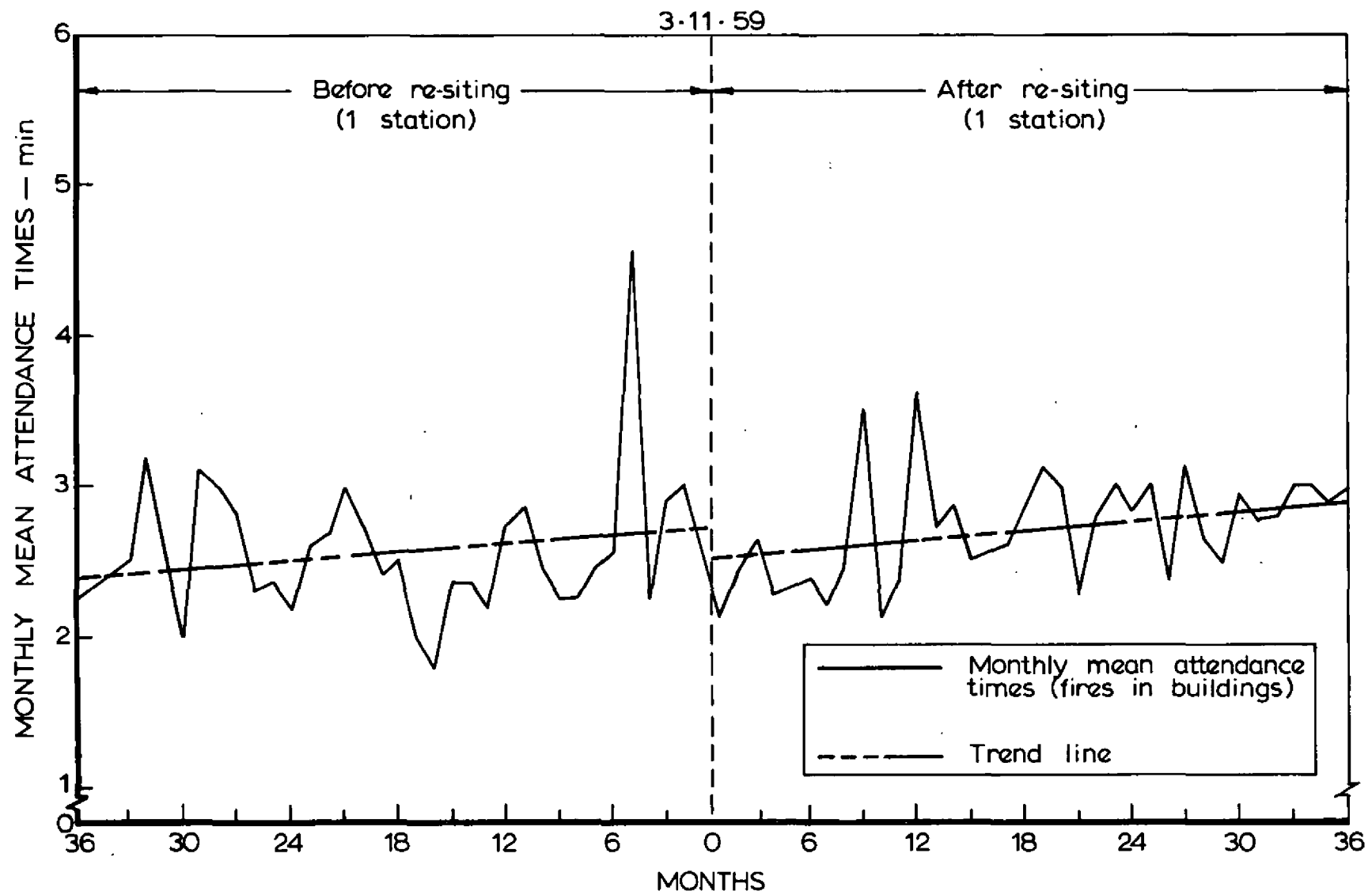FIG. 13. BRIGADE "N"

FIG.14. BRIGADE "P"

FIG. 15. BRIGADE "Q"

FIG. 16. BRIGADE "R"