

Report on the Observation of Pulsatory Oscillations in Japan. *1st Paper.*

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With Pls. I—V.

1. *Introduction.** The present paper is a preliminary note on the study of pulsatory oscillations in Japan, executed in consequence of a resolution adopted at the Hague Conference in 1907 of the International Seismological Association, having for the object, amongst others, the observation of these movements on some isolated islands and the comparison of motion at several stations within a small area. The results of my previous investigations on pulsatory oscillations have already been given in the Journal of the College of Science, Tokyo Imperial University, Vol. XI (1899); the Publications of the Earthquake Investigation Committee, No. 5 (1901) and No. 13 (1903); and in the *Toyo Gakugei Zasshi*, Vol. XXV (1908).

With regard to the nature of motion, pulsatory oscillations were found to be probably due to the translatory movements, and not to the inclination, of the ground. Again, their periods are seen to vary, in the majority of cases, between about 4 sec. and about 8 sec., there being two fundamental periods, whose mean values have been found to be respectively

* This paper was read on Oct. 7th, 1908, at a meeting of the Imperial Earthquake Investigation Committee.

$$Q_1=4.4 \text{ sec.} \quad Q_2=8.0 \text{ sec.}$$

These mean periods seem to be constant, or approximately so, all over the earth.

2. Observations on Mount Tsukuba, and in the islands of O-shima and Hachijo. According to the observations made in Japan, the pulsatory oscillations occur very often, in fact more or less at all times, on the extensive quarternary plains, such as those of Tokyo and Osaka, and on large alluvial valleys such as that of Mizusawa (province of Rikuchu). On the contrary, these movements were found to occur very seldom and only to a slight degree at Arima (province of Settsu), Kyoto, and Miyako (province of Rikuchu), places which are situated on granite or on paleozoic rocks. The existence of pulsatory oscillations on mountains of hard rocks has been confirmed by the observation made by the late Prince Yamashina on Mount Tsukuba, a massive granite and diorite block, which rises to the height of 870 metres, out of the low ground on the border of the lower course of the river Tone; some small but distinct movements of about 4 sec. period being indicated in the diagrams furnished by an Omori horizontal pendulum of 50 times magnification at the observatory on the top of the mountain.

The seismological observation in the islands of O-shima and Hachijo has been taken up as a case of the pulsatory oscillations in volcanic districts, these two islands belonging both to the Fuji volcanic chain.

The record of pulsatory oscillations in the island of O-shima was made in August 1908 with a horizontal pendulum apparatus of 30 times magnification, whose heavy mass had a natural period of 30 sec. The maximum range of motion (in the EW component) was 0.02 mm, the average periods of the pulsatory oscillations

on the different days ranging between 2.7 and 6.5 sec., with the mean value of **4.3** sec., as follows:—

2.7 sec.	4.4 sec.
2.7	4.5
2.9	4.6
3.0	4.7
3.2	4.7
3.3	4.9
3.6	4.9
3.6	5.2
3.8	5.3
3.8	5.4
3.9	5.4
3.9	5.4
4.2	6.5
4.4	mean 4.3

It seems that pulsatory oscillations are in O-shima of a frequent occurrence, and belong mostly to the Q_1 class. The predominance of the latter class movements seems also to be the case in the island of Hachijo, where the pointer of a horizontal tremor recorder of 150 times magnification and of a pendulum period of about 5 sec. was often thrown into movements of considerable amplitude.

3. Pulsatory oscillations have hitherto been studied chiefly by means of the seismological instruments recording the horizontal motion. But the movements in question are not, of course, confined to the latter component alone; the vertical pulsatory oscillations being, as indicated in § 4, sometimes apparently large.

4. *Vertical pulsatory oscillations.* Pulsatory oscillations are also indicated by the vertical motion seismographs adapted to continuous registration, set up at Hongo. These vertical

movements, whose occurrence is apparently rarer than that of the horizontal components, attained sometimes the double amplitude of 0.4 mm. The principal machine is essentially a Gray-Ewing type vertical motion seismograph with some modifications for reducing the friction between its parts, the instrumental constants being as follows :—

Length of the vertical springs = 1.2 metres.

Horizontal distance between the centre of the steady mass and the pivot = 1.2 metres.

Weight of the heavy 'bob' = 9 kg.

Multiplication of the pointer = 12.

Complete oscillation period of the pendulum = 5.0 sec.

As an example, I give here some measurements of the amplitude* and period from the diagrams for March 4th–5th, 1904, and March 23rd–24th, 1907 :—

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
(I)		(II)	
3.1 sec.	0.11 mm.	4.2 sec.	0.18 mm.
3.1	0.11	4.3	0.04
3.2	0.06	4.6	0.33
3.4	0.08	4.6	0.33
3.5	0.13	4.6	0.23
3.3 (mean)		4.7	0.37
		4.7	0.35
		4.8	0.28
		4.9	0.25
		4.6 (mean)	

* The double amplitude, or range of motion is denoted by $2a$.

The mean periods of the two groups (I) and (II) in the above table are **3.3** and **4.6** sec., which may be regarded as being approximately equivalent to the two periods of q and Q_1 classes of the horizontal pulsatory oscillations. (See § 8.)

5. The observations discussed in the subsequent §§ relate, unless otherwise stated, to the EW component motion at the Seismological Institute in the University compound at Hongo, Tokyo, registered by an Omori horizontal pendulum tromometer, whose instrumental constants were as follows:—

Weight of the heavy bob = 50 kg.

Vertical distance between the point of support and the point of suspension = 1 metre.

Length of the strut = 20 cm.

Horizontal distance between the point of support and the writing index = 120 cm.

Multiplication ratio of the pointer = 120.

Pendulum period = 21 sec.

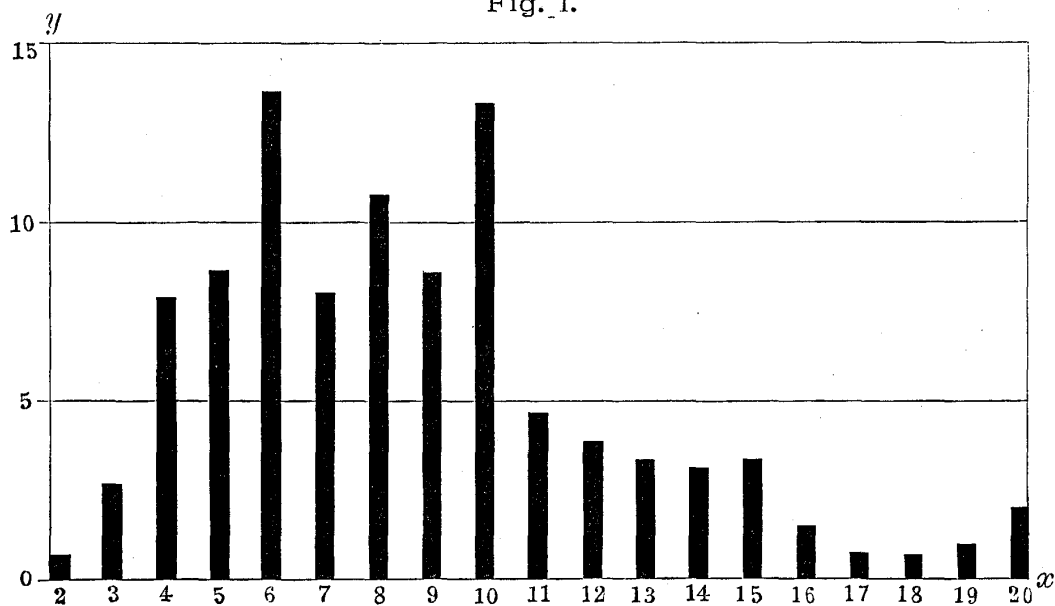
In § 11, a comparison is made between the pulsatory oscillations simultaneously observed at Hongo and Hitotsubashi, which latter place is the former site of the Tokyo Imperial University and is in the lower part of the city.

Horizontal Pulsatory Oscillations.

6. **Records.** To examine closely the vibration period of the pulsatory oscillations, a few of the 120 times horizontal tromometer records obtained at Hongo have photographically been enlarged 8 to 10 times so as to produce a final magnification of 1,000 to 1,200 times. Some of the larger movements thus enlarged attain a double amplitude of over 15 cm, with a time

scale of about 24 cm. for one minute. Instead of taking, as done heretofore, at once 50 or 100 consecutive movements, the average periods have been deduced each from a group of well defined

Fig. 1.



and nearly isochronous vibrations, whose number ($=x$) usually varied from 4 to 10, as is illustrated in Fig. 1 and is shown in the following percentage table :—

x = Number of well defined and nearly isochronous vibrations composing a maximum group.	y = Relative Frequency.
2	0.7 %
3	2.7
4	7.9
5	8.6
6	13.7
7	8.1
8	10.8
9	8.6
10	13.3
11	4.7

Number of well defined and nearly isochronous vibrations composing a maximum group.	Relative Frequency.
12	3.9 %
13	3.4
14	3.2
15	3.4
16	1.5
17	0.7
18	0.7
19	1.0
20	2.0
21	0.0
22	0.0
23	0.2
24	0.0
25	0.0
26	0.2
27	0.0
28	0.2
29	0.0
30	0.2

The tromometer diagrams, whose parts have, for the sake of examination, been photographically enlarged, relate to the EW component records obtained at Hongo on the following dates :—

(A)

{ 1908, January 30 and 31.
 „ , February 28 to March 1.
 „ , September 8 to 10.

(B)

{ 1907, June 19 and 20.
 1908, January 21.
 „ , February 1.
 „ , March 5 to 8.
 „ , March 30 and 31.
 „ , April 13 and 14.

The two divisions (A) and (B) give examples respectively of the predominance of the pulsatory oscillations of slower and those of quicker period. Illustrative diagrams are given on Pls. III to V, as follows :—

Pl. III. March 8, 1908: large pulsatory oscillations of quick period (Q_1).

Pl. IV. Feb. 29, 1908: slow period pulsatory oscillations (Q_2) of large amplitude, mixed with minute vibrations (q) of short period.

Pl. V. January 30 and 31, 1908: small slow pulsatory oscillations (Q_2), mixed with traces of minute vibrations (q) of short period.

7. *Pulsatory oscillations of slow period.* Tables I to VI give the average periods and the corresponding maximum double amplitude ($2a$) observed at Hongo, on some of the different dates in 1908, when the slow vibrations predominated.

From Tables I to VI it will be observed that the period of the slow pulsatory movements, or Q_2 oscillations, varied between about 6.2 and 9.9 sec., with the mean value of **7.5** sec. Their maximum range of motion was 0.083 mm, the vibrations greater than 0.05 mm occurring rarely, as is shown by the following list of the relative frequency of the different amplitudes :—

$2a$ (Range of motion).	Frequency.
0.011-0.020 mm.	44.5 %
0.021-0.030	28.9
0.031-0.040	13.9
0.041-0.050	9.0
0.051-0.060	1.8
0.061-0.070	0.6

2 <i>a</i> (Range of motion).	Frequency.
0.071–0.080 mm.	0.6 %
0.081–0.090	0.6

Mixed with the slow pulsatory oscillations, there are to be found more or less traces of small quick vibrations whose period varied generally between 2.3 and 3.4 sec., with the mean value of **2.9** sec., the maximum range of motion being 0.012 mm. This class of motion may provisionally be called *q* vibrations.

The number of occurrences of each of the different periods of the Q_2 and *q* classes, which appeared in the diagrams of the slow pulsatory oscillations, is given in Table VII. As will be seen from the illustrations in Fig. 3 (Pl. I), the length of period ranged from 2.3 sec. up to 9.9 sec., with the exception of 3.6 to 6.3 sec., between which interval the movements of importance happened very rarely. It thus appears that in the cases under examination, the movement of the ground was essentially made up of the Q_2 class oscillations, mixed with some very small *q* class vibrations, while the Q_1 class movements were almost entirely wanting.

To see the relation, if any, between the period and the amplitude of the pulsatory oscillations, I give in Table VIII the frequencies of the different periods for the motion greater than 0.02 mm and for that greater than 0.04 mm. It will be observed that the large movements occurred in the majority of cases at the periods between about 6.5 and about 8.2 sec., but most frequently at the period of 6.8 sec. It is hereby interesting to note that the pulsatory oscillations recorded at Hongo on Nov. 17th and 18th, 1900, which were the greatest so far observed in Japan and whose maximum range of motion was 0.65 mm in each horizontal component, had also an average period of 6.8 sec.

Again, the large pulsatory oscillations on Oct. 11th, 1904, also observed at Hongo, whose EW component motion was 0.35 mm, had an average period of about 6.6 sec. It is probable that very marked pulsatory oscillations occur generally with periods of 6.5 to 7.0 sec.

s. Pulsatory oscillations of quick period (Q_1). From Tables IX to XIV, which give the average periods and the corresponding maximum double amplitudes of the pulsatory oscillations of the Q_1 class, it will be seen that the period of the principal, or larger, vibrations varied between 3.5 and 6.4 sec., giving the mean value of **4.5** sec. The motion attained often a range of 0.06 mm, and sometimes of 0.1 mm, the maximum being 0.139 mm. The relative frequencies of the different amplitudes, over 0.02 mm, were as follows :—

2 a (Range of motion).	Frequency.
0.021–0.030 mm.	22.5 %
0.031–0.040	23.1
0.041–0.050	15.4
0.051–0.060	13.0
0.061–0.070	6.5
0.071–0.080	7.7
0.081–0.090	4.1
0.091–0.100	5.3
0.101–0.110	0.6
0.111–0.120	0.6
0.121–0.130	0.6
0.131–0.140	0.6

Mixed with the Q_1 oscillations, there were also some small vibrations of the q class, whose maximum range was 0.026 mm, and whose period varied between 2.3 and 3.4 sec., with the mean value of **2.9** sec.

The frequencies of the different periods of the Q_1 and q classes ranging between 2.3 and 6.4 sec. are indicated in Table XV, the illustration being given in Fig. 2. The periods occurring most frequently were included between 3.5 and 5.4 sec. Again, according to Table XVI, which gives the frequencies of the different periods for the movements over 0.05 mm and for those over 0.08 mm, the larger pulsatory oscillations occurred more often with the periods between 4.2 and 5.6 sec., especially between 5.2 and 5.5 sec. It is, however, likely that the vibrations of this class, which occur very much more frequently than those of the Q_2 class, do not attain such a large range of motion as in the case of the latter.

Comparing Fig. 2 with Fig. 3, it will be observed that the prominent pulsatory oscillations of the Q_1 class and those of the Q_2 class are, on the whole, mutually exclusive. In other words, the Q_1 movements, which are of a most frequent occurrence, almost cease to appear when the Q_2 movements are predominating. The small q vibrations occurred together both with the Q_1 and the Q_2 oscillations. The two dotted lines (A) and (B) in Figs. 2 and 3 have been drawn from these considerations so as to mark off with regard to period, the Q_1 , Q_2 and q classes of the oscillations from each other. To recapitulate the mean values of the periods of these three classes are as follows:—

q	2.9 sec.
Q_1	4.5
Q_2	7.5

These values are only provisional.

9. *Observations at Hongo and Hitotsubashi, 1898–1900.*

For the sake of reference I give in Table XVII a list of the frequencies of the different periods of the pulsatory oscillations

in the EW direction observed in 1898–1900 at Hongo and Hitotsu-bashi; the periods having in each case been deduced from some 50 or 100 consecutive vibrations in a diagram, and the frequency being the number of cases, namely, days on which each particular period occurred.* The Q_1 period may, for these observations, be regarded as being included between 3.4 and 5.8 sec., and the Q_2 period between 6.2 and 9.3 sec.; the mean periods of the two classes of oscillations being respectively **4.3** and **7.4** sec. These results, which refer to the movements not always large, are approximately the same as those obtained in the preceding paragraphs. According to Table XVII, the pulsatory oscillations of Q_1 class occurred 4 times more frequently than those of the Q_2 class.

10. *Relation between pulsatory oscillations and barometric pressure.* It is well known that the approach of a deep barometric depression is invariably accompanied by the production of marked pulsatory oscillations, which belong in the majority of cases to the Q_1 class. The slower movements of the Q_2 class seem, however, to occur under some special meteorological conditions, as may be inferred from the following table, which gives the barometric pressure† and the wind strength in Tokyo for each of the dates of occurrence of the slow pulsatory oscillations in 1908 (§ 7) and in 1900.**

* See the "Publications of the Earthquake Investigation Committee", Nos. 4 and 13.

† With the freezing point, sea-level, and gravity reductions.

** The "Publications of the Earthquake Investigation Committee", No. 13.

Date	Pulsatory Oscillations.		Meteorological Conditions (at 6 am.)		
	Period.	Max. 2 <i>a</i>	Barometric Pressure. (Tokyo)	Wind Strength (Tokyo)	Remarks.
[Observation at Hongo, 1908.]					
Jan. 30	sec. sec. 6.8-8.0	mm 0.020	767.2 mm	1	Whole Japan* covered by high pressure, max. = 770 mm. Centre of low pressure (= 764 mm) off the east coast of Corea, another centre of low pressure (= 765 mm) off the coast of Tosa.
„ 31			757.2	0	Centre of low pressure (= 748 mm) in the Japan sea, between Corea and Iwami.
Feb. 28	6.7-9.3	0.054	768.4	2	Whole Japan covered by high pressure, max. = 772 mm. Centre of low pressure (= 760 mm) off the S. end of Formosa.
„ 29	6.2-9.9	0.046	768.1	2	Centre of low pressure (= 758 mm) off the SW. coast of Kyushyu.
March 1	6.9-8.4	0.028	761.9	3	Whole Japan covered by high pressure, max. = 771 mm. Centre of low pressure (= 757 mm) off the peninsula of Awa, and another centre of low pressure (= 758 mm) in the Japan sea off the coast of San-in-do.
Sept. 8	4.8-7.6	0.039	762.5	4	Whole Japan covered by high pressure, max. = 768 mm. Centre of low pressure (= 755 mm) off the E. coast of Formosa.
„ 9			763.2	2	Whole Japan covered by high pressure, max. = 766 mm. Centre of low pressure (= 754 mm) at some distance to the E. of Formosa.
„ 10	6.5-7.9	0.083	762.2	2	Positions of high (= 764 mm) and of low pressure (= 753 mm) same as on the preceding day.

Date	Pulsatory Oscillations.		Meteorological Conditions (at 6 am.)		
	Period.	Max. 2 α	Barometric Pressure. (Tokyo)	Wind Strength. (Tokyo)	Remarks.
[Observation at Hitotsubashi, 1900.]					
sec. Jan. 24	sec. 7.1	sec. 0.05	760.7 mm	1	Whole Japan covered by pressure of 760 to 765 mm.
Feb. 17	8.1	small	774.6	2	Whole Japan covered by high pressure, max. = 775.7 mm.
„ 20	8.1	small	765.4	1	Centre of low pressure (= 762 mm) to the S. of Kyushyu and E. of Formosa.
Nov. 7	7.5	0.06	762.3	0	Whole Japan covered by high pressure, max. = 767.3 mm.
{ „ 19	9.3	0.06	767.4	2	Whole Japan covered by high pressure, max. = 766.1 mm.
{ „ 20			767.7	2	Whole Japan covered by high pressure, max. = 769.3 mm.
					Same as on the preceding day, max. = 770.9 mm. Centre of low pressure (= 760 mm) off the S. end of Formosa.

* (Whole Japan here signifies the Main Island and the three other principal islands of Hokkaido, Shikoku, and Kyushyu.)

A remarkable fact, which is at once evident from the above table is that, on the days of occurrence of the slow pulsatory Q_2 oscillations, the wind strength in Tokyo was generally very weak, and varied, with one exception, between 0 and 3; while the barometric pressure in the same city was always nearly equal to, or much higher than, the ordinary value. I give here, for the sake of comparison, the mean monthly barometric heights in Tokyo, deduced from the observations during the 30 years, 1876-1905 :—

Month.	Mean Barometric Height.*	Month.	Mean Barometric Height.*
January	761.7 mm	July	756.7 mm.
February	762.0	August	757.5
March	761.6	September	759.2
April	761.2	October	762.1
May	758.6	November	762.5
June	756.6	December	761.5

Again, from the remarks given in the preceding table, it will be seen that on each of the days under consideration, the Main Island, together with Hokkaido, Shikoku, and Kyushyu, formed an area of high atmospheric pressure. In four out of the fourteen cases, the maximum barometric height within the latter area was from 765 to 769.3 mm, there being no marked centre of atmospheric depression in the vicinity of the Japanese islands. In the remaining ten cases, five of which were accompanied by specially high values of the pressure ranging between 770 and 776 mm, there existed barometric depressions off the coast of Formosa or Kyushyu or in the Japan sea. These depressions themselves were, except in one case, not very deep. It thus appears that the necessary conditions for the production of the slow pulsatory oscillations, say of the Q_2 vibrations of period over 7 sec., is the existence of a high barometric pressure over Japan, with or without the simultaneous appearance of some low pressure centre in the neighbourhood of Formosa or western Japan; the barometric gradient being, under these circumstances, not steep.

11. Comparison of pulsatory oscillations between Hongo and Hitotsubashi. To compare the pulsatory oscillations at

* With the freezing point, sea-level, and gravity reductions.

different places within a small area, some observations of the Q_1 movements have been made simultaneously at Hongo and Hitotsubashi with similar horizontal pendulum tromometers. Fig. 4 (Pl. II) shows the diagrams thus obtained at these two stations on Feb. 1st, 1908. At Hongo the ground is high and hard, while at Hitotsubashi the ground is low and very soft, the mutual distance being 2.29 km.

On comparing the movements at same instants of time in the diagrams simultaneously obtained at Hongo and Hitotsubashi, it was found impossible to identify the individual vibrations at the two places. In other words, the motion at Hongo differed from that at Hitotsubashi, not only in phase, but also in the arrangement of pulsatory oscillations into groups of maximum and minimum. The period of vibration was, however, the same at the two places; the amplitude being increased at Hitotsubashi to a slight degree. Thus, according to Table XVIII, which gives the elements of motion at different instants in the time interval between 0 h 8 m and 0 h 51 m, pm., on Feb. 1st., 1908, the mean result of the comparison was as follows :—

	Hongo.	Hitotsubashi.
Average period	5.29 sec.	5.31 sec.
Max. $2a$	0.080 mm.	0.085 mm.

Again, according to Table XIX, which relates to the time interval of 0 h 33 m to 1 h 16 m, pm., on Jan. 21st, 1908, we have the following result :—

	Hongo.	Hitotsubashi.
Average period	4.25 sec.	4.27 sec.
Max. $2a$	0.047 mm.	0.057 mm.

That the period and amplitude of the pulsatory oscillations

should be nearly constant at places not much distant from each other is easy to understand. It is, however, difficult to explain why the form of motion, or variation of amplitude of the successive movements, differs between Hongo and Hitotsubashi, as the Q_1 oscillations have sufficiently long period and consequently ought not to be much affected by the difference in the nature of soil within a small area.

12. Conclusion. As remarked in § 1, the phenomena of pulsatory oscillations, especially with regard to the periods of vibration, seem to be practically the same all over the earth. For establishing such a general theorem, it is of course necessary to examine a sufficient number of the diagrams from different seismological observatories of the world. Among the many interesting problems connected with the movements in question, the most fascinating one is the study of the motion of the ground on, or at the immediate vicinity of, an active volcano. From this point of view, the Italian seismological observatories of Catania, Mineo, and of Valle di Pompei, are to be considered as occupying very favourable and important positions. It is also my intention to make further observations on pulsatory oscillations on volcanic mountains in Japan.

TABLE I. Q_2 AND q PULSATORY OSCILLATIONS ON JAN. 30 AND 31, 1908.

HONGO. EW COMPONENT.

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
3.5 sec.	0.003 mm	7.3 sec.	0.012 mm
		"	0.006
6.8	0.006	"	0.011
7.0	0.006	"	0.010
"	0.007	"	0.009
"	0.005	7.4	0.010
7.1	0.011	"	0.010
"	0.010	"	0.011
"	0.010	"	0.011
7.2	0.006	7.5	0.020
"	0.004	7.7	0.007
7.3	0.003	7.8	0.015
"	0.008	8.0	0.006
"	0.006		
"	0.007		

TABLE II. PULSATORY OSCILLATIONS ON FEB. 28 AND 29, 1903.

HONGO. EW COMPONENT.

Q_2 Pulsatory Oscillations.				q Pulsatory Oscillations.	
Average Period.	Max. 2 a .	Average Period.	Max. 2 a .	Average Period.	Max. 2 a .
6.7 sec.	0.020 mm	8.1 sec.	0.008 mm	1.9 sec.	0.002 mm
7.1	19	"	46	2.0	4
"	12	"	3	2.6	3
7.2	20	"	31	"	3
7.3	7	8.2	14	2.7	4
"	16	"	54	"	3
"	15	"	30	"	(Small)
"	21	"	26	"	2
"	24	"	42	"	3
"	19	8.3	22	2.8	5
7.5	13	"	7	"	3
"	14	8.4	9	2.9	4
"	18	"	44	"	3
7.6	20	"	7	"	3
"	46	8.5	6	3.0	5
"	32	"	39	"	4
"	7	8.6	23	"	3
7.7	33	8.7	5	3.1	5
"	9	"	4	"	5
"	19	8.8	20	"	5
"	9	"	6	3.2	6
"	19	"	14	"	6
7.8	23	"	39	"	4
"	13	8.9	6	"	2
"	22	"	21	"	6
"	37	"	22	"	3
"	6	9.0	29	3.3	3
7.9	10	"	13	3.4	5
"	46	9.1	9	3.5	3
"	29	9.3	6	3.7	3
"	22	"	7	3.9	7
"	8				

TABLE III. PULSATORY OSCILLATIONS ON FEB. 29, 1908.

HONGO. EW COMPONENT.

Q_2 Pulsatory Oscillations.				q Pulsatory Oscillations.	
Average Period.	Max. $2a$.	Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
6.2 sec.	0 040 mm	7.9 sec.	0.021 mm	0.86 sec.	(small)
6.6	9	„	17	1.3	(small)
6.8	18	8.0	7	1.7	0.002 mm
„	15	8.1	16	2.4	4
6.9	17	„	8	„	4
7.0	25	„	12	2.6	3
7.2	14	8.2	10	„	4
„	18	„	7	2.7	4
7.3	10	8.3	21	„	5
„	17	„	16	2.9	4
7.4	16	„	18	3.0	5
„	37	8.4	12	„	5
7.5	24	8.5	29	„	4
„	37	9.0	21	„	4
„	14	9.1	9	„	4
7.6	18	9.9	26	3.1	6
7.8	19			3.2	4
„	46			3.3	4
				„	6
				3.5	5

TABLE IV. PULSATORY OSCILLATIONS ON FEB. 29-MARCH 1, 1903.

HONGO. EW COMPONENT.

Q_2 Pulsatory Oscillations.		q Pulsatory Oscillations.			
Average Period.	Max. $2a$.	Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
6.9 sec.	0.011 mm	2.2 sec.	0.005 mm	2.9 sec.	0.008 mm
7.2	15	2.3	4	"	8
7.3	14	"	2	"	7
7.4	12	2.4	6	3.0	12
7.5	17	"	3	3.1	7
"	15	"	6	"	7
"	14	"	5	"	7
"	12	"	5	3.2	5
"	16	2.5	3	"	9
7.6	10	"	6	"	7
"	21	"	2	"	6
7.7	28	2.6	5	3.4	9
7.8	10	"	7	"	9
"	15	"	7	"	5
"	10	"	3	3.5	9
8.0	12	2.7	4	"	7
8.1	9	"	6	3.6	6
"	13	"	7	4.1	5
"	14	"	6		
8.3	10	"	10		
8.4	15	2.8	9		
		"	6		

TABLE V. Q_2 AND q PULSATORY OSCILLATIONS ON SEPT. 8-9, 1908.
HONGO. EW COMPONENT.

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
3.4 sec.	0.006 mm	7.0 sec.	0.025 mm
3.6	4	"	13
3.8	4	"	33
"	4	"	25
4.0	7	7.1	28
4.8	11	"	28
"	20	"	21
5.7	13	"	25
5.8	21	7.2	35
6.4	19	"	29
"	28	"	17
"	23	"	13
6.5	18	"	25
"	28	"	17
"	17	7.3	24
6.7	18	"	31
"	18	"	21
6.8	17	"	39
"	18	"	19
"	35	7.4	28
6.9	26	"	17
"	27	"	30
"	24	"	33
"	21	7.5	13
		"	8
		"	14
		7.6	34

TABLE VI. Q_2 AND q PULSATORY OSCILLATIONS ON SEPT. 9-10, 1908.

HONGO. EW COMPONENT.

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
3.1 sec.	0.005 mm	6.8 sec.	0.045 mm
4.7	5	"	29
4.9	26	"	55
5.1	6	"	46
5.4	9	"	46
5.5	12	6.9	23
5.6	12	"	38
5.8	13	"	46
5.9	9	"	83
6.3	13	7.0	29
6.5	51	"	35
"	49	7.1	22
"	50	"	25
6.6	20	"	37
"	24	7.2	28
"	61	"	37
6.7	50	7.3	17
"	74	7.4	8
6.8	33	"	40
"	14	7.5	33
"	45	7.9	5
"	45		

TABLE VII. FREQUENCY OF THE DIFFERENT PERIODS OF
THE PULSATORY OSCILLATIONS.

BASED ON TABLES I—VI.

Period.	Number of cases.	Period.	Number of cases.
2.3 sec.	2	6.0 sec.	—
2.4	6	6.1	—
2.5	3	6.2	1
2.6	8	6.3	1
2.7	12	6.4	3
2.8	4	6.5	6
2.9	7	6.6	4
3.0	9	6.7	5
3.1	8	6.8	15
3.2	11	6.9	10
3.3	3	7.0	10
3.4	5	7.1	12
3.5	5	7.2	14
3.6	2	7.3	24
3.7	1	7.4	13
3.8	2	7.5	16
3.9	1	7.6	8
4.0	1	7.7	7
4.1	1	7.8	11
4.2	—	7.9	8
4.3	—	8.0	3
4.4	—	8.1	10
4.5	—	8.2	7
4.6	—	8.3	6
4.7	1	8.4	5
4.8	2	8.5	3
4.9	1	8.6	1
5.0	—	8.7	2
5.1	1	8.8	4
5.2	—	8.9	3
5.3	—	9.0	3
5.4	1	9.1	2
5.5	1	9.2	—
5.6	1	9.3	2
5.7	1	9.4	—
5.8	2	9.5	—
5.9	1	9.6	—
		9.7	—
		9.8	—
		9.9	—

TABLE VIII. FREQUENCY OF THE DIFFERENT PERIODS OF THE
PULSATORY OSCILLATIONS OF MAX. $2a > 0.02$ mm.
AND OF MAX. $2a > 0.04$ mm.
BASED ON TABLES I-VI.

Period.	Number of cases :	
	$2a > 0.02$ mm.	$2a > 0.04$ mm.
4.8 sec.	1	0
4.9	1	0
5.8	1	0
6.2	1	1
6.3	0	0
6.4	2	0
6.5	4	3
6.6	3	1
6.7	3	2
6.8	9	6
6.9	8	2
7.0	6	0
7.1	7	0
7.2	6	0
7.3	6	0
7.4	5	1
7.5	3	0
7.6	5	1
7.7	2	0
7.8	4	1
7.9	4	1
8.0	0	0
8.1	2	1
8.2	4	2
8.3	2	0
8.4	1	1
8.5	2	0
8.6	1	0
8.7	0	0
8.8	2	0
8.9	2	0
9.0	2	0
9.9	1	0

TBLE IX. Q_1 AND q PULSATORY OSCILLATIONS ON JUNE 19-20, 1907.

HONGO. EW COMPONENT.

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
3.5 sec.	0.010 mm.	4.3 sec.	0.036 mm.
3.6	38	"	65
3.7	7	"	50
3.8	38	"	58
"	67	4.4	71
3.9	42	"	67
4.0	28	"	58
4.1	50	"	33
"	38	4.5	56
"	28	4.7	70
4.2	37	"	72
"	73	5.0	26
"	36	5.1	56
"	42	5.3	53
"	62		

TBLE X. Q_1 AND q PULSATORY OSCILLATIONS ON JAN. 21, 1908.

HONGO. EW COMPONENT.

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
3.7 sec.	0.016 mm.	4.4 sec.	0.052 mm.
3.8	50	"	37
"	35	"	45
4.0	38	4.5	42
4.1	46	"	72
4.2	55	4.6	52
4.3	60	"	47
"	41		
"	51		
"	38		
"	54		

TABLE XI. Q_1 AND q PULSATORY OSCILLATIONS ON FEB. 1, 1908.
HONGO. EW COMPONENT.

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
4.3 sec.	0.018 mm.	5.4 sec.	0.092 mm.
4.8	75	"	96
4.8	64	"	87
4.9	78	"	92
"	72	5.5	87
"	87	"	105
5.1	62	"	78
5.2	95	5.6	65
"	96	5.8	124
"	80	5.9	48
"	112		
5.3	95		
"	85		
"	77		
"	78		
"	80		
"	87		
"	87		

TABLE XII. Q_1 AND q PULSATORY OSCILLATIONS ON MARCH
5, 6, AND 8, 1908.

HONGO. EW COMPONENT.

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
2.5 sec.	0.004 mm.	4.8 sec.	0.087 mm.
2.6	3	4.9	41
"	13	5.0	57
2.8	6	"	59
"	6	"	46
3.5	15	5.0	38
3.6	6	"	43
"	12	"	97
3.7	29	"	16
3.8	91	5.1	33
"	45	"	13
"	8	5.2	50
"	15	"	49
"	16	"	53
3.9	20	5.3	55
"	57	"	68
"	11	"	57
"	9	"	50
"	40	"	34
4.0	62	5.4	40
"	31	"	38
4.1	34	"	139
"	11	"	78
"	11	5.5	50
4.2	32	"	93
4.3	8	5.6	53
"	14	"	25
4.6	35	"	65
"	32	5.8	42
"	26	"	58
4.7	37	"	60
"	50	6.0	11
4.8	44	6.1	27
"	54	6.4	10
"	52		

TABLE XIII. Q_1 AND q PULSATORY OSCILLATIONS ON
MARCH 30-31, 1903.

HONGO. EW COMPONENT.

Average Period.	Max. 2 a .	Average Period.	Max. 2 a .
3.3 sec.	0.006 mm.	4.2 sec.	0.033 mm.
"	7	"	34
3.6	14	"	37
3.7	26	"	33
3.9	8	"	27
"	13	4.3	37
"	29	"	33
"	33	"	24
"	41	"	39
"	25	4.4	39
4.0	45	"	16
"	26	4.5	38
"	27	"	26
4.1	27	"	37
"	26	"	35
"	27	"	32
"	36	4.6	29
"	28	"	45
"	37	4.7	47
"	28	"	19
		4.8	35
		5.1	23

TABLE XIV. Q_1 AND q PULSATORY OSCILLATIONS ON
APRIL 13-14, 1908.

HONGO. EW COMPONENT.

Average Period.	Max. $2a$.	Average Period.	Max. $2a$.
2.3 sec.	0.009 mm.	3.5 sec.	0.006 mm.
2.4	21	"	22
"	18	"	16
2.5	12	3.6	17
"	17	"	21
2.6	19	3.7	21
"	17	"	15
"	14	"	15
2.7	12	"	22
"	15	"	22
"	14	"	18
2.8	6	3.8	17
"	26	3.9	18
2.9	6	"	25
"	20	"	17
"	17	"	16
"	18	"	29
3.0	6	4.0	20
"	6	"	28
"	9	"	21
"	25	4.2	24
"	11	4.3	24
3.1	23	"	14
"	19	4.5	21
"	25	"	17
"	19	"	11
"	13	4.6	13
3.2	19	4.7	21
3.3	18	"	13
"	13	4.8	16
3.4	24	5.1	17
3.5	22		
"	22		

TABLE XV. FREQUENCY OF THE DIFFERENT PERIODS OF
THE PULSATORY OSCILLATIONS.

BASED ON TABLES IX—XIV.

Period.	Number of cases	Period.	Number of cases.
2.3 sec.	1	4.5 sec.	11
2.4	2	4.6	9
2.5	3	4.7	8
2.6	5	4.8	7
2.7	3	4.9	4
2.8	4	5.0	8
2.9	4	5.1	6
3.0	5	5.2	7
3.1	5	5.3	13
3.2	1	5.4	8
3.3	4	5.5	5
3.4	1	5.6	4
3.5	7	5.7	—
3.6	6	5.8	4
3.7	10	5.9	1
3.8	10	6.0	1
3.9	16	6.1	1
4.0	11	6.2	—
4.1	14	6.3	—
4.2	13	6.4	1
4.3	18		
4.4	9		

TABLE XVI. FREQUENCY OF THE DIFFERENT PERIODS OF THE
PULSATORY OSCILLATIONS OF MAX. $2a > 0.05$ mm
AND OF MAX. $2a > 0.08$ mm.

BASED ON TABLES IX–XIV.

Period.	Number of cases. $2a > 0.05$ mm	Number of cases. $2a > 0.08$ mm
3.8 sec.	3	1
3.9	1	0
4.0	1	0
4.1	1	0
4.2	3	0
4.3	6	0
4.4	4	0
4.5	2	0
4.6	1	0
4.7	3	0
4.8	5	1
4.9	3	1
5.0	3	1
5.1	2	0
5.2	6	4
5.3	12	5
5.4	6	5
5.5	5	3
5.6	3	0
5.7	0	0
5.8	3	1
5.9	0	0
6.0	0	0

TABLE XVII. FREQUENCY OF THE DIFFERENT PERIODS OF THE
PULSATORY OSCILLATIONS OBSERVED AT HONGO
AND HITOTSUBASHI IN 1899-1900.

Period.	Number of cases.	Period.	Number of cases.
3.4 sec.	2	6.5 sec.	0
3.5	1	6.6	1
3.6	3	6.7	1
3.7	4	6.8	1
3.8	8	6.9	1
3.9	10		
		7.0	0
4.0	5	7.1	1
4.1	2	7.2	2
4.2	7	7.3	2
4.3	5	7.4	0
4.4	7		
		7.5	2
4.5	6	7.6	0
4.6	5	7.7	2
4.7	0	7.8	1
4.8	2	7.9	0
4.9	2		
		8.0	2
5.0	4	8.1	2
5.1	5	8.2	0
5.2	1	8.3	0
5.3	3	8.4	0
5.4	0		
		8.5	0
5.5	1	8.6	0
5.6	2	8.7	0
5.7	2	8.8	0
5.8	2	8.9	0
5.9	0		
		9.0	0
6.0	0	9.1	0
6.1	0	9.2	0
6.2	1	9.3	1
6.3	0	9.4	0
6.4	2		

TABLE XVIII. COMPARISON OF PULSATORY OSCILLATIONS
OBSERVED AT HONGO AND HITOTSUBASHI.
FEB. 1, 1908.

Time. (PM)	Hongo.		Hitotsubashi.	
	Average Period.	Max. 2 α .	Average Period	Max. 2 α .
0 ^h 8 ^m -10 ^m	5.4 sec.	0.092 mm	— sec.	— mm
9 -11	—	—	5.8	0.104
12 -13	5.5	87	—	—
11 -14	—	—	5.4	92
13 ¹ / ₂ -14 ¹ / ₂	—	—	5.1	80
14 -15	5.5	105	—	—
14 ¹ / ₂ -15 ¹ / ₂	—	—	5.0	54
15 -16	4.9	78	—	—
16 -19	5.5	78	5.6	76
19 -20	4.3	18	—	—
19 ¹ / ₂ -22 ¹ / ₂	—	—	5.3	117
20 -21	5.4	96	—	—
21 -24	5.3	95	—	—
22 ¹ / ₂ -24	—	—	5.1	100
24 -25 ¹ / ₂	4.8	64	5.7	60
25 -26	5.4	87	—	—
26 -28	5.3	85	—	—
27 -30	5.3	77	—	—
25 ¹ / ₂ -29 ¹ / ₂	—	—	5.3	110
30 -31	5.3	78	—	—
31 ¹ / ₂ -33	—	—	5.1	62
31 -32	5.2	95	—	—
32 ¹ / ₂ -33 ¹ / ₂	5.6	65	—	—
34 -35	—	—	5.6	65
35 -40	—	—	5.6	87
40 -42	5.2	96	—	—
42 -43 ¹ / ₂	—	—	5.4	102
43 -46	5.3	80	—	—
45 -47	—	—	4.5	74
46 -48	5.9	48	—	—
47 -48	—	—	5.0	76
48 -49	5.2	80	5.6	102
49 -51	5.3	87	5.3	77
mean	5.29	0.080	5.31	0.085

TABLE XIX. COMPARISON OF PULSATORY OSCILLATIONS,
OBSERVED AT HONGO AND HITOTSUBASHI.
JAN. 21, 1908.

Time. (PM)	Hongo		Hitotsubashi.	
	Average Period.	Max. 2 α .	Average Period.	Max. 2 α .
^h 0 ^m 33 $\frac{1}{2}$ - ^m 34 $\frac{2}{3}$	3.8 sec.	0.050 mm	— sec.	— mm
34 - 35	—	—	4.1	0.075
35 - 36	4.4	52	4.2	45
37 - 38	4.3	60	4.5	46
38 - 39	4.6	47	4.5	48
39 - 40 $\frac{1}{2}$	3.8	35	4.1	50
40 $\frac{1}{2}$ - 41 $\frac{2}{3}$	4.4	37	—	—
42 - 44	4.2	55	4.3	62
44 $\frac{2}{3}$ - 45 $\frac{1}{2}$	4.1	46	—	—
45 $\frac{1}{2}$ - 47	—	—	4.7	56
47 - 49	4.3	41	4.1	40
49 - 54 $\frac{2}{3}$	—	—	4.0	50
53 - 56	4.3	51	4.2	42
56 - 58	4.5	42	4.5	74
58 - 59	—	—	4.2	38
59 - 60	—	—	4.3	70
^h 1 ^m 0 $\frac{1}{2}$ - 3	4.4	45	4.4	70
3 $\frac{1}{2}$ - 4 $\frac{1}{2}$	—	—	4.0	66
4 - 7	4.3	54	4.0	55
7 - 8	4.0	38	4.3	44
8 - 9	—	—	4.4	54
9 - 10	3.7	16	—	—
10 - 11 $\frac{1}{2}$	4.5	72	4.1	84
12 - 14 $\frac{1}{2}$	4.6	52	—	—
14 - 15 $\frac{1}{2}$			4.6	65
mean	4.25	0.047	4.27	0.057

Frequency of the different Periods of Pulsatory Oscillations, showing the mutual exclusion of the two series of movements of Q_1 and Q_2 classes.

For Figs. 2 and 3:—
 x = Period.
 y = Frequency, or number of times of occurrence, of a given period x .

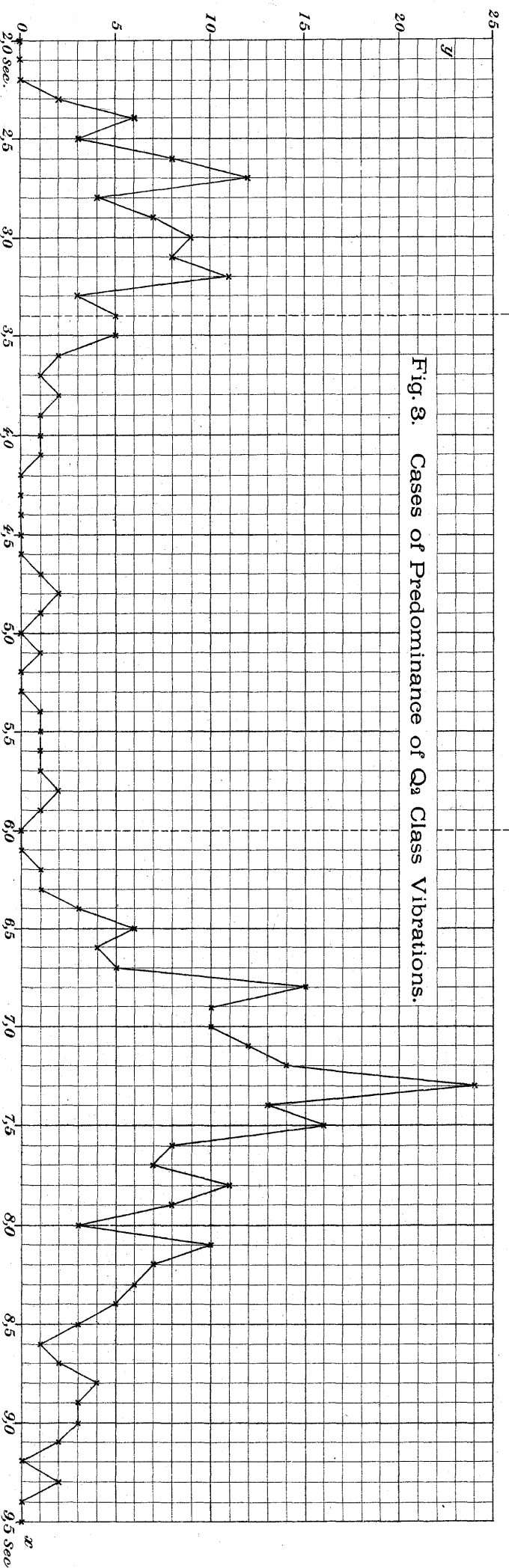
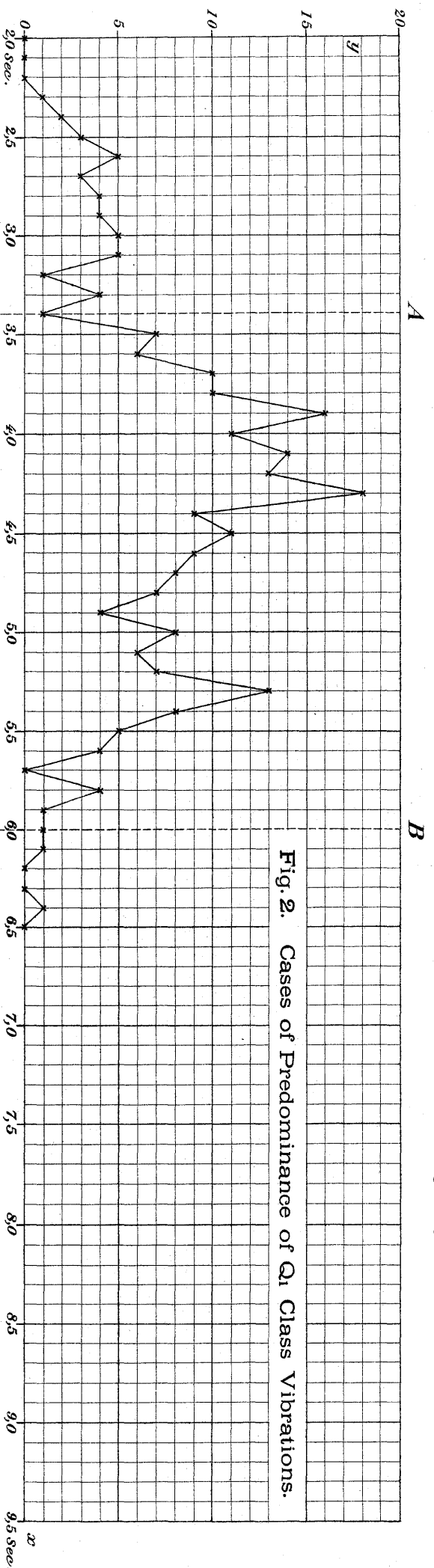


Fig. 4. Comparison of Pulsatory Oscillations on Feb. 1, 1908,
observed at the two stations of Hongo and Hitotsubashi in Tokyo.

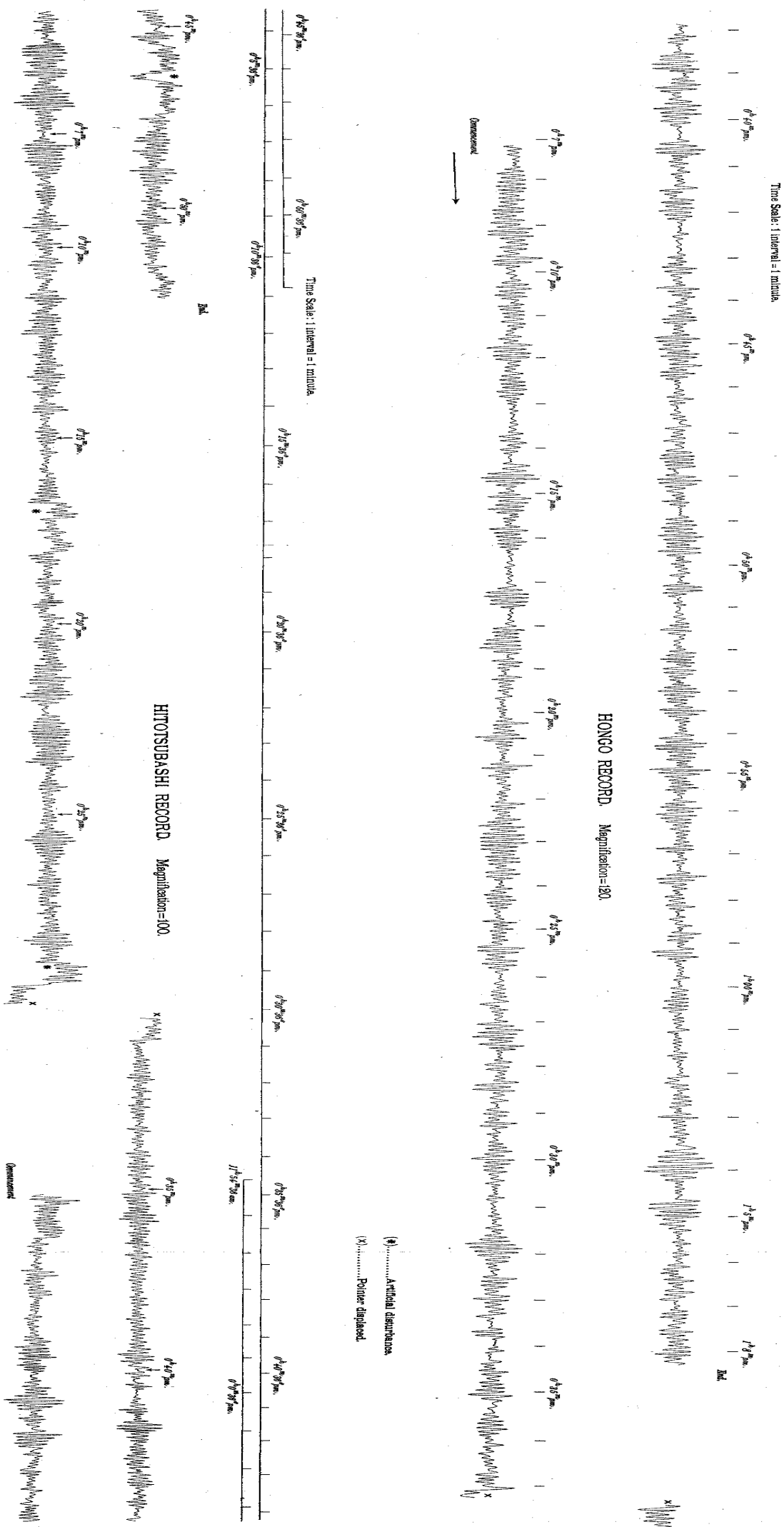


Fig. 5. EW Component Tromometer Record of Pulsatory Oscillations
of Q_1 Class on March 8, 1908, at Hongo, Tokyo.

(Original Pointer Multiplication=120; Pendulum Period=21 sec)
Magnification = 1067 times.

Time Scale : the interval between successive time marks (short vertical dots) = 1 minute.

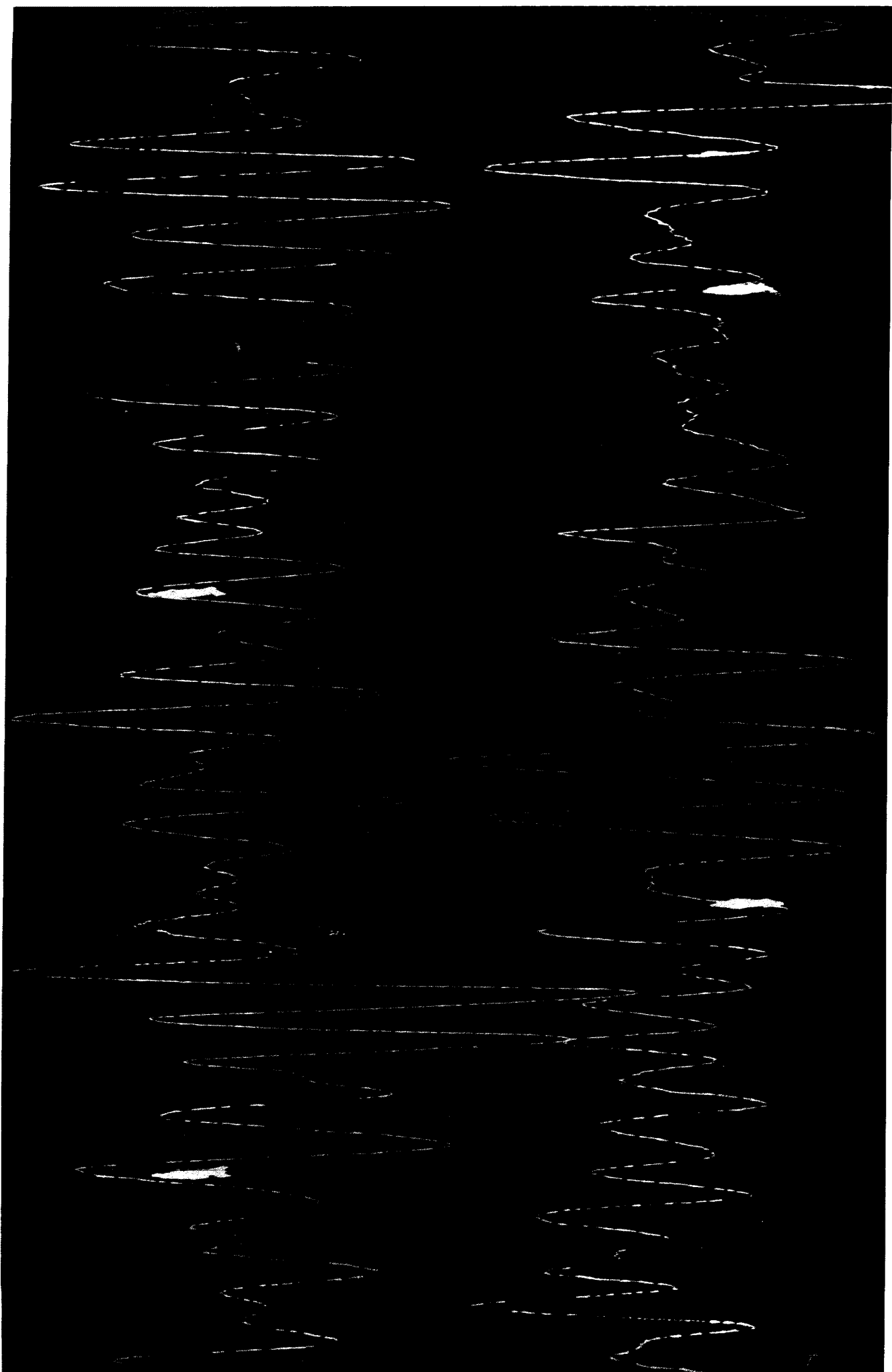
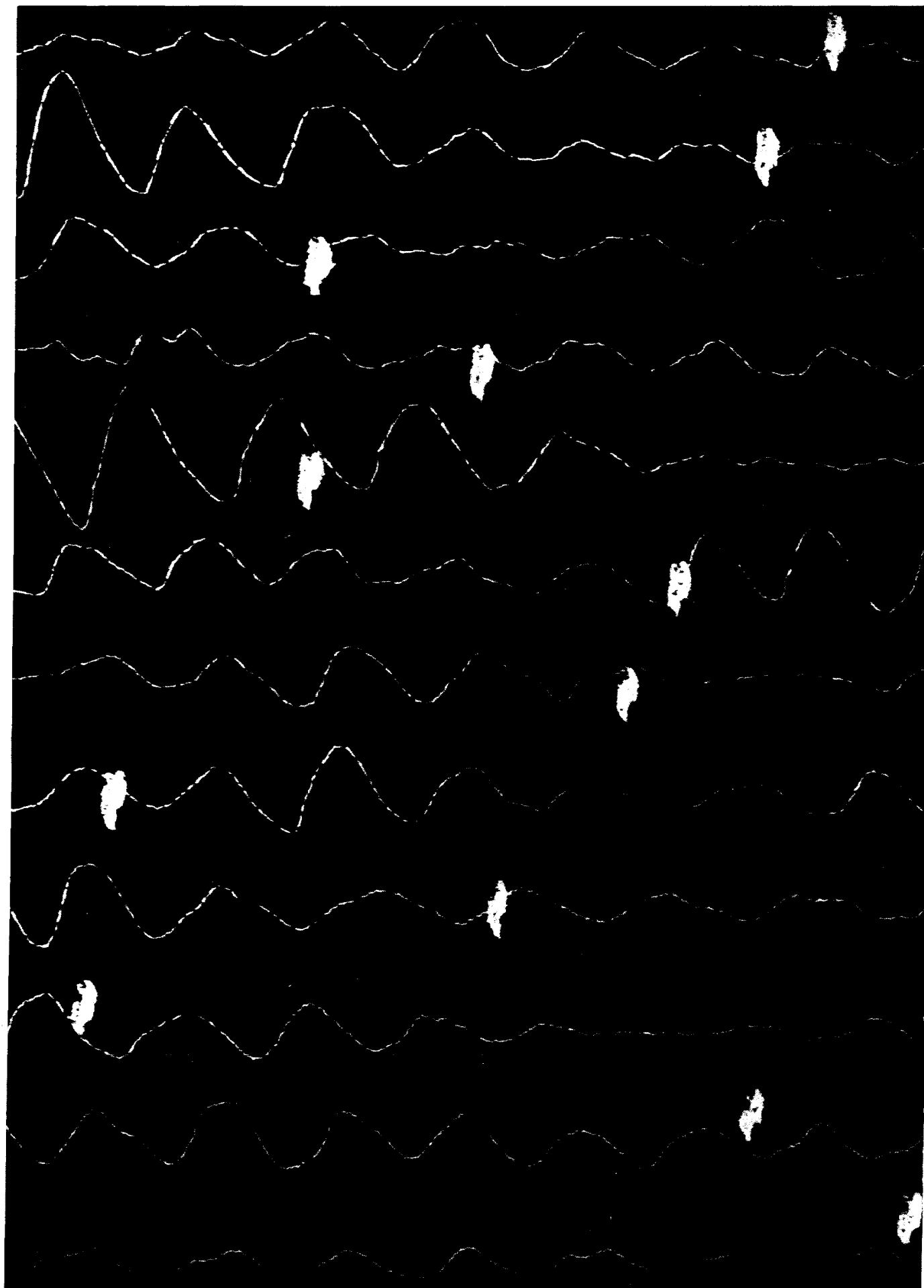


Fig. 6. EW Component Tromometer Record of Pulsatory Oscillations of Q₂ Class on Feb. 29, 1908, at Hongo, Tokyo.

(Original Pointer Multiplication=120; Pendulum Period=21 sec.)
Magnification=1209 times. Time Scale: 1 minute=238 mm.
(Short vertical dots are marks of minutes of time).



Time Scale

0 sec. 5 10 20 30 sec.

Fig. 7. EW Component Tromometer Record of Pulsatory Oscillations
of Q_2 Class on Jan. 30-31, 1908, at Hongo, Tokyo.

(Original Pointer Multiplication = 120; Pendulum Period = 21 sec)

Magnification = 1046 times.

Time Scale: the interval between successive time marks (short vertical dots) = 1 minute.

