Application of Seismographs to the Measurement of the Vibration of Railway Carriages.

(2nd Paper.)

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With Plates I-VIII.

Introduction.

1. The following pages give an account of the measurement of the vibration of the experimental carriage, or "shayo-sha," of the Sanyo Railway, the record having been taken continuously through the length of 89 miles of the up and down lines between Kobe and Okayama. The vibration measurers, which were set up at the middle of the floor of the carriage, were exactly similar to those in the previous series of experiments.* On April 26, 1903, when the measurement was made, the weather was fine and calm.

The "shayo-sha," which was throughout the experiment coupled directly to a tender engine, was an ordinary 3rd class (non-Bogie) carriage, the tires of whose wheels were, for a certain experimental purpose, made cylinder-shaped. The down train started from Kobe at 10.30 a.m. and reached Okayama at 1.20 p.m.; while the up train started from the latter place at 3.45 p.m. and reached the former at about 7 p.m.

A special feature of interest in the present experiment is that both

* F. Omori: Application of seismographs to the measurement of the vibration of railway carriages. The *Publications*, No. 15.

the down and up trains were express ones and attained often a velocity of about 50 miles per hour, thereby enabling us, amongst other things, to investigate the effect of *curves* and *point crossings* on the vibration of the carriage.

The rail joints used on the Sanyo Railway are similar to what is known in the Government Railways as the 1st kind of joint, namely, the usual form which consists of two simple fish plates.*

2. ***Velocity of the Train.*** The velocity of the train was measured by a velocity recorder set up in the same carriage as the vibration measurers. The mean velocity between any two consecutive mile posts can also be accurately found from the record of the time-marking pendulum; the moments of transit of the carriage past the successive mile posts, as well as the bridges, culverts, and road-crossings, having been marked down by means of a signalling arrangement. By comparing the indications of the velocity recorder with the velocities actually deduced from the records of the time-ticker, the following mean results were obtained.

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* See the *Publications*, No. 15, p. 53.

TABLE I.

Indication from the velocity recorder $= V'$.	Actual velocity deduced from the record of the time-marking pendulum $= V$.	Correction to be subtracted from the indication of the velocity recorder $= V' - V$.
miles/hour.	miles/hour.	miles/hour.
26.	24.7	1.3
31.8	28.5	3.3
34.	31.3	2.7
36.	34.2	1.8
38.	36.2	1.8
39.	37.0	2.0
40.	37.5	2.5
42.	40.5	1.5
45.	43.7	1.3
47.8	45.5	2.3
50.2	47.8	2.4
MEAN		**2.1**

Thus it will be seen that the indication of the velocity recorder was about 2 miles per hour greater than the real velocity. As, however, the difference was small, I have taken in the following pages the values of the speed indicated by the velocity recorder without correction.

The highest value of the indicated velocity reached in the present experiment was 53 miles per hour, which corresponds to the actual velocity of about 51 miles per hour.

MOTION OF THE CARRIAGE ON BRIDGES.

3. All the bridges on the Sanyo Railway between Kobe and Okayama consist of plate girders of 70′ or shorter spans; the 60′ and 70′ girders are of steel, while the shorter ones are of wrought iron. One of the longest bridges is that over the Kako-gawa, near the station of the same name, consisting of one 50′ and seventeen 70′ plate girders.

Lateral vibration of the carriage.* The following table, which relates to seventeen of the longer bridges, gives the elements of the maximum lateral vibration of the carriage, "shayo-sha," during its passage over each of the bridges; the movements being, for the sake of convenience, divided into three groups, according to the period of vibration.†

TABLE II. LATERAL VIBRATION OF THE CARRIAGE (SHAYO-SHA) WHEN PASSING OVER THE PLATE GIRDER BRIDGES. UP AND DOWN TRAINS. SANYŌ RAILWAY.

Velocity.	Max. $2a$.	T	Velocity.	Max. $2a$.	T.	Velocity.	Max. $2a$.	T
miles/hour.	mm.	sec.	miles/hour.	mm.	sec.	miles/hour.	mm.	sec.
23	3.0	0.29	27	4.0	0.66	30	13.0	0.95
23	3.0	0.36	27–30	8.0	0.73	37	17.0	0.80
24	5.0	0.36	30	6.0	0.62	38	16.0	1.46
27	2.0	0.26	32	5.0	0.55	38	24.0	0.84
27–30	2.5	0.33	38	6.0	0.73	38–39	28.0	1.24
32	2.0	0.22	38	8.0	0.47	39½	16.0	0.91
38–39	3.0	0.23	38	18.0	0.55	39½	21.0	1.02
41–43	5.0	0.33	38–39	5.0	0.51	41–42	22.0	0.88
			42	7.0	0.69	42	28.0	1.02
			41–43	12.0	0.55	43	18.0	1.13
			43	6.0	0.55			
			43	17.0	0.73			
			48	11.0	0.77			
Mean. 30	3.2	0.30	*Mean.* 38	8.7	0.62	*Mean.* 39	20.3	1.03

* The examination is here limited to the lateral component alone.

† The notations $2a$ and T are used always for the *double amplitude* and the *complete period* of vibration respectively.

From the above table it will be seen that the mean values of the max. $2a$ corresponding to the mean periods of 0.30, 0.62, and 1.03 sec., were respectively 3.2, 8.7, and 20.3 mm: in other words, the three periods were roughly in the ratios of 1 : 2 : 3, while the three corresponding maximum amplitudes were roughly in the ratios of 1 : 3 : 6. The absolutely greatest $2a$'s in the three groups of vibration were 5, 18 and 28 mm respectively.

For the sake of reference I give in the following table the maximum lateral vibration of the experimental carriage, "kyokuyo-sha," of the Government Railways when passing over the different plate girder bridges on the Tōkaidō line.*

TABLE III. LATERAL VIBRATION OF THE CARRIAGE (KYOKUYO-SHA) WHEN PASSING OVER THE PLATE GIRDER BRIDGES. 1ST AND 2ND EXPERIMENTS. TOKAIDO RAILWAY.

Velocity.	Max. $2a$.	T	Velocity.	Max. $2a$.	T
miles/hour.	mm.	sec.	miles/hour.	mm.	sec.
17	9.8	0.57	23	22	0.83
20	20	0.62	27	20.8	0.98
22	11	0.66	27	23	0.92
24	19	0.71	28	27	1.06
25	18	0.54	29	17	0.76
27	15.2	0.61	—	14	0.84
27	10	0.43	—	15.2	0.86
27	31	0.67	27—30	18	0.79
28	18	0.61			
27—29	21	0.66			
29	17	0.66			
Mean.			*Mean.*		
25	**17.3**	**0.61**	**27**	**20**	**0.88**

* Table III has been constructed from the results of Experiments I and II on the Tōkaidō Railway. The *Publications*, No. 15.

A comparison of Tables II and III shows that the lateral vibration of the "kyokuyo-sha" when crossing over the bridges on the Tōkaidō Railway, for velocities between 25 and 27 miles per hour, was somewhat greater than that of the "shayo-sha" on the Sanyo line bridges, for velocities between 30 and 39 miles per hour. This probably depends on the difference in the quality of the springs supporting the bodies of the carriages, and also possibly on the difference in the forms of the wheel tires.

VERTICAL VIBRATION OF THE CARRIAGE.

[On the ground.]

4. The vertical vibration of the crrriage was always very small, the greast $2a$ during the whole experiment being 14.5 mm. When the velocity of the train was high and approached the value of some 40 miles per hour, there appeared also small and very quick vibrations, whose max. $2a$ did not exceed 2.1 mm. These latter vibrations may, for the sake of convenience, be called *tremors*. (For illustrative diagrams, see Pls. III to V.) The following table gives the $2a$ and T of the maximum vibration and tremor of the carriage corresponding to the different velocities on the first 35 miles of the down line.

TABLE IV. VERTICAL VIBRATION OF THE CARRIAGE "SHAYO-SHA." DOWN TRAIN. SANYO RAILWAY.

Distance from Kobe.	Velocity.	Max. Vibration.		*Tremor.*	
		$2a$	T	$2a$	T
Miles	miles/hour.	mm.	sec.	mm.	sec.
2	23	1.5	0.34		
	24	1.7	0.34		
	25	1.4	—		
	26	1.2	—		
	27	1.5	—		
	28	1.9	—		
	29	1.5	—		
	30	1.6	—		
$2\frac{1}{4}$	31	2.4	—		
	32	2.4	—		
	33	3.0	0.25		
$2\frac{1}{2}$	33	2.3	0.30		
	32	1.7	0.25		
$2\frac{3}{4}$	$32\frac{1}{2}$	2.6	0.25		
3	33	3.5	0.25		
$3\frac{1}{4}$	34	2.6	0.22		
$3\frac{1}{2}$	35	10.0	0.34		
$3\frac{3}{4}$	"	3.0	0.24		
4	"	3.0	0.31		
$4\frac{1}{4}$	"	3.0	0.22		
	"	4.4	0.27		
	34	3.0	0.22		
	31	4.5	0.25		
$4\frac{1}{2}$	31	4.2 1.5	0.30 0.21		
Suma St.	—	3.5	0.25		
$4\frac{3}{4}$	27	3.0	0.23		

Distance. from Kobe.	Velocity.	Max. Vibration.		*Tremor.*	
		$2a$	T	$2a$	T
Miles.	miles/hour.	mm.	sec.	mm.	sec.
$7\frac{1}{2}$	40	4.0 3.0	0.20 0.21		
(Thereafter, quick *tremors* appeared.)					
$7\frac{3}{4}$	41	5.0 5.0	0.30 0.56	1.7	0.068
	42	2.4	0.25	1.5	0.047
8	43	3.0 7.0	0.25 0.65	2.0	0.068
Tarumizu. Station.	42	1.7 6.0	0.16 0.51	1.8	0.068
$8\frac{1}{4}$	—	4.0	0.21	1.2	0.065
$8\frac{1}{2}$	39	3.2	0.25	0.7	—
9	41	3.5 4.5	0.25 0.51	1.2	—
$9\frac{3}{4}$	$41\frac{1}{2}$	5.0	0.25	2.0	0.076
	$40\frac{1}{2}$	—	—	1.3	—
$10\frac{1}{4}$	38	3.2 1.0	0.20 0.59	—	—
$10\frac{1.5}{2}$	39	2.7	0.27	1.2	0.055
$10\frac{3}{4}$	40	3.0	0.24	1.5	0.055
11	41	3.8 4.2	0.25 0.64	1.5	0.068
$11\frac{1}{4}$	42	3.2	0.24	1.9	0.064
$11\frac{3}{4}$	43	3.0	0.25	1.6	—
Akashi St.	43	2.5 7.0	0.24 0.51	2.0	0.062
$12\frac{1}{4}$	43	2.8	0.22	1.1	0.065

TABLE IV. (*Continued.*)

Distance from Kobe.	Velocity.	Max. Vibration.		*Tremor.*	
		$2a$	T	$2a$	T
miles.	$\frac{\text{miles.}}{\text{hour.}}$	mm.	sec.	mm.	sec.
$12\frac{1}{2}$	42	2.0	0.25	1.0	—
	41	3.4	0.25	1.0	0.064
	42 ..	{ 2.0 .. 14.5	{ 0.17 .. 0.63	.. 1.7	0.085
13 (On bridge.)	43	3.1	0.21	2.0	0.074
(Maximum epochs of the *tremors* occurred at a regular interval of 3.7 sec.)					
$13\frac{1.5}{4}$	37	3.0	0.22	1.0	0.068
$13\frac{1}{2}$	36	2.1	0.25	1.1	—
	35	3.0	0.23	1.3	—
$13\frac{3}{4}$	33	3.0	0.22	2.0	—
14	33	3.6	0.25	1.5	—
	34	3.1	0.25	1.1	—
$14\frac{1}{4}$	35	6.0	0.25	0.9	—
	37	3.2	0.17	0.9	—
$14\frac{1}{2}$	38	5.2	0.34	1.0	—
$14\frac{3}{4}$	$38\frac{1}{2}$ ..	{ 5.0 .. 4.2	{ 0.52 .. 0.26	.. 1.0	—
15	39	4.0	0.27	—	—
$15\frac{1}{4}$	40	3.0	0.24	—	—
	41	{ 6.0 .. 5.0	{ 0.27 0.47	—	—
	42	{ 3.5 .. 3.0	{ 0.24 0.16	—	—
$15\frac{1}{2}$	40	{ 3.0 .. 6.5	{ 0.22 0.85	—	—
$15\frac{3}{4}$	38	{ 2.5 .. 7.0	{ 0.20 0.64	—	—
Okubo St.	35–34 ..	{ 4.0 .. 4.0 .. 2.1	{ 0.30 0.76 0.20	—	—

Distance from Kobe.	Velocity.	Max. Vibration.		*Tremor.*	
		$2a$	T	$2a$	T
miles.	$\frac{\text{miles.}}{\text{hour.}}$	mm.	sec.	mm.	sec.
16	33	2.8	0.21	1.0	0.065
$16\frac{1}{4}$	35	—	—	1.1	—
	36	3.2	0.25	1.0	0.064
$16\frac{1}{2}$	37	3.6	0.26	0.8	0.059
	38	2.2	0.22	1.1	—
$17\frac{1}{2}$	42	3.0	0.21	2.1	0.065
$17\frac{3}{4}$	40	3.0	0.24	1.4	0.065
	38	4.0	0.25	1.0	—
18	$38\frac{1}{2}$	2.2	0.20	1.2	0.068
$18\frac{1}{4}$	39	3.1	0.25	1.9	0.076
	40	—	—	1.9	—
$18\frac{1}{2}$	41	2.4	0.25	1.5	—
	42	2.4	0.24	1.4	0.068
	$44\frac{1}{2}$	2.3	0.21	2.1	0.064
$18\frac{3}{4}$	46	2.8	0.20	1.6	—
	45	2.0	0.20	2.0	—
	46	—	—	1.8	—
	47	2.5	0.21	1.4	—
	43	3.5	0.22	1.9	0.065
	42	3.0	0.24	1.1	0.055
$19\frac{3}{4}$	40	2.0	0.21	1.2	—
	38	2.5	0.20	1.4	0.068
Tsuchi-yama St.	36	2.0	0.27	1.0	—
	35	2.3	0.25	1.1	—
	34	2.8	0.25	1.2	—
	$34\frac{1}{2}$	—	—	1.9	—

TABLE IV. (*Continued.*)

Distance from Kobe.	Velocity.	Max. Vibration.		*Tremor.*	
		$2a$	T	$2a$	T
miles.	miles/hour.	mm.	sec.	mm.	sec.
$20\frac{1}{4}$	38	2.8	0.23	—	—
$20\frac{1}{2}$	39	3.2	0.21	1.0	0.068
$21\frac{1}{4}$	40	3.0	0.25	0.9	0.068
$21\frac{1}{2}$	41	1.8	0.17	1.5	0.065
	42	2.7	0.22	2.0	0.068
	43	2.7	0.21	1.2	0.064
22	44	2.5	0.21	1.9	0.064
	45	3.5	—	2.0	0.064
	46	4.0 / 4.4	0.20 / 0.47	1.0	—
$22\frac{1}{2}$	47	2.5 / 4.0	0.17 / 0.42	1.5	0.072
$22\frac{1.5}{2}$	48	2.2	0.21	1.9	0.066
	47	2.2	0.20	2.0	0.065
23	46	3.5	0.17	1.3	0.065
$23\frac{1}{4}$	49	2.6	0.20	1.9	0.064
$23\frac{1}{2}$	50	3.7 / 7.0	0.21 / 0.47	2.0	0.059
„	49	4.5	0.24	1.5	0.063
24	48	2.8 / 5.2	0.17 / 0.42	1.6	0.064
Kakogawa St.	45	2.0	0.19	1.2	0.064
$24\frac{1}{2}$	47	3.2	0.19	1.4	0.072
	44	3.0	0.22	1.0	—
25	39	2.2	0.25	—	—
„	41	3.6 / 8.2	0.19 / 0.93	1.2	—
$25\frac{1}{2}$	45	5.0 / 9.5	0.20 / 0.47	1.6	—

Distance from Kobe.	Velocity.	Max. Vibration.		*Tremor.*	
		$2a$	T	$2a$	T
miles.	miles/hour.	mm.	sec.	mm.	sec.
Hoden St.	37	5.0	0.25	2.1	0.065
$26\frac{1}{2}$	38	8.0	0.47	1.4	—
29	38	3.6	0.24	1.0	0.064
„	$38\frac{1}{2}$	3.3	0.21	1.0	—
33	40	4.0	0.25	0.4	—
	39	5.0	0.25	—	—
	38	5.5	0.25	—	—
	37	6.0	0.30	1.0	0.059
	36	3.6	0.25	0.7	—
	28	4.0	0.27	—	—
	25	4.0	0.34	1.0	—
	22	3.0	0.25	—	—
34	20	3.5	0.38	—	—
	18	2.6	—	—	—
	16	3.2	—	—	—
	14	3.5	0.25	—	—
	14	1.0	0.24	—	—
	(Arrives at Himeji St.)				
	(Small.)	1.2	0.22	—	—
	16	3.0	0.38	—	—
	18	3.4	0.30	—	—
$34\frac{1}{4}$	19	4.6	0.34	—	—
	20	3.2	—	—	—
	21	4.1	—	—	—
	22	5.0	0.38	—	—
	23	5.8	0.38	—	—
	24	3.6	—	—	—
	$25\frac{1}{2}$	5.0	0.42	—	—
$34\frac{1}{2}$	26	3.2	0.30	—	—
	27	4.2	0.29	—	—

TABLE IV. (*Continued.*)

Distance from Kobe.	Velocity.	Max. Vibration.		*Tremor.*		Distance from Kobe.	Velocity.	Max. Vibration.		*Tremor.*	
		2a	*T*	*2a*	*T*			*2a*	*T*	*2a*	*T*
miles.	miles./hour.	mm.	sec.	mm.	sec.	miles.	miles./hour.	mm.	sec.	mm.	sec.
$34\frac{1}{2}$	$28\frac{1}{2}$	5.9	0.41	—	—	$34\frac{1}{2}$	35	5.0	0.38	—	—
	29	5.6	0.42	—	—						
	30	3.6	0.32	—	—						
						$35\frac{1}{4}$	37	5.0	—	—	—
							38	3.8	—	—	—
"	31	4.5	0.25	—	—		39	3.0	0.21	—	—
	32	6.4	0.28	—	—	$35\frac{1}{2}$	$39\frac{1}{2}$	4.6	0.21	1.0	—
	33	4.2	0.25	—	—						
	34	4.0	—	—	—		40	3.0	0.29	—	—

As will be seen from the above table, the fundamental vertical vibrations of the carriage, "shayo-sha," were essentially of two kinds, namely, the quicker movements of period varying between 0.16 and 0.42 sec., and of comparatively slow ones of period varying between 0.47 and 0.93 sec. These two classes of motion may provisionally be termed the vibration of the 1st kind and the vibration of the 2nd kind.

The vibration of ths 1st kind existed always and the periods most frequently occurring were those between 0.20 and 0.27 sec.; the general average value deduced from the 139 cases contained in Table IV being 0.25 sec. The absolutely maximum *2a* of the vibration of this kind was 10 mm (period=0.34 sec.) The relative frequencies of the different periods of the vibration of the 1st kind were as follows.

Period.	Number of cases.	Period.	Number of cases.
sec.		sec.	
0.16	2	0.30	7
0.17	6	0.31	1
0.18	0	0.32	1
0.19	3	0.33	0
0.20	12	0.34	7
0.21	17	0.35	0
0.22	12	0.36	0
0.23	3	0.37	0
0.24	11	0.38	5
0.25	36	0.39	0
0.26	2	0.40	0
0.27	6	0.41	1
0.28	1	0.42	4
0.29	2		

Prominent vibrations of the 2nd kind occurred rarely, and, in fact, only when the velocity of the train was greater than 35 miles per hour. The average value of the period deduced from the 18 cases contained in Table IV is 0.59 sec., the absolutely greatest $2a$ being 14.5 mm. The relative frequencies of the different periods of the vibration of the 2nd kind were as follows.

Period.	Number of cases.	Pericd.	Number of cases.
sec.		sec.	
0.47	5	0.64	2
0.51	3	0.65	1
0.52	1	0.76	1
0.56	1	0.85	1
0.59	1	0.93	1
0.63	1		

The periods of the *tremors* varied between 0.047 and 0.085 sec., giving an average value of 0.066 sec.

5. *Relation between the vertical vibration and the velocity.* The following table gives the $2a$ of the maximum vertical vibration corresponding to the different values of the velocity of the train, based on Table IV; the relation between the velocity and the mean value of the $2a$ being illustrated in fig. 1.

TABLE V. RELATION BETWEEN VERTICAL VIBRATION OF THE CARRIAGE, "SHAYŌ-SHA," AND THE VELOCITY OF THE TRAIN. DOWN TRAIN. SANYO RAILWAY.

Velocity.	Max. $2a$.	
miles/hour.	mm	(mean).
14	3.5	
16	3.2 3.0	3.1
18	2.6 3.4	3.0
19	4.6	
20	3.2 3.5	3.4
21	4.1	
22	3.0 5.0	4.0
23	5.8 1.5	3.7
24	1.7 3.6	2.7
25	1.4 4.0	2.7
26	5.0 1.2 3.2	3.1
27	1.5 3.0	2.3
28	4.2 4.0 1.9 5.9	4.0

Velocity.	Max. $2a$.	
miles/hour.	mm	(mean).
29	5.6 1.5	3.6
30	1.6 3.6	2.6
31	2.4 4.5 4.2 4.5	3.9
32	6.4 2.4 1.7	3.5
33	2.6 3.0 2.3 3.5 4.2 3.0 3.6 2.8	3.1
34	2.6 3.0 4.0 2.8 3.1 4.0 2.1	3.1

Velocity.	Max. $2a$.	
miles/hour.	mm	(mean).
35	2.3 5.0 10.0 3.0 3.0 3.0 4.4 3.0 6.0	4.4
36	3.2 2.1 3.6 2.0	2.7
37	3.6 5.0 6.0 5.0 3.0 3.2	4.3
38	5.2 2.5 3.2 3.8 8.0 3.6 5.5 2.2 4.0 2.5 2.8	3.9

TABLE V. (*Continued.*)

Velocity.	Max. $2a$.
miles/hour.	mm (mean).
39	2.2, 3.3, 4.2, 4.0, 3.2, 2.7, 3.0, 2.2, 5.0, 3.1, 3.2 } **3.3**
40	4.6, 3.0, 3.0, 2.0, 3.0, 4.0, 3.0, 4.0, 3.0, 3.0, 6.5 } **3.6**

Velocity.	Max. $2a$.
miles/hour.	mm (mean).
41	3.4, 6.0, 5.0, 3.5, 3.8, 3.6, 2.4, 1.8 } **3.7**
42	5.0, 3.2, 2.0, 2.0, 3.5, 2.4, 1.7, 3.0, 2.4, 3.0, 2.7 } **2.8**
43	3.5, 2.7, 3.0, 3.0, 2.5, 2.8, 3.1 } **2.9**

Velocity.	Max. $2a$.
miles/hour.	mm (mean).
44	2.5, 3.0 } **2.8**
45	2.3, 2.0, 3.5, 2.0, 5.0 } **3.0**
46	2.8, 4.0, 3.5 } **3.4**
47	2.2, 3.2, 2.5, 2.5 } **2.6**
48	2.2, 2.8 } **2.5**
49	2.6, 4.5 } **3.6**
50	3.7

According to fig. 1, the mean relation between the velocity of the train and the vertical vibration is approximately represented by a circular arc: the $2a$ gradually increased till the velocity reached the value of 35 miles per hour, when it attained the maximum (mean) value of about 3.5 mm. Thereafter the vertical vibration decreased, the mean value corresponding to the velocity of about 50 miles per hour being about 2.8 mm, or approximately equal to the motion corresponding to the velocity of about 18 miles per hour.

The general character of the curve in fig. 1 is nearly equal to that in fig. 9 on page 48 of the *Publications*, No. 15, which represents the relation between the velocity and the vertical vibration of the "kyokuyo-sha" of the Government Railways on the Tokaido line. There is, however, a considerable difference in the amount of the vertical vibration corresponding to the different velocities, between the two cases, as shown in the following table:—

Velocity.	Average value of Max. Vert. Vibration.	
	"Shayo-sha" (Sanyo Railway).	"Kyokuyo-sha" (Tokaido Railway).
miles/hour.	mm.	mm.
8	—	5.6
15	—	9.6
19	3.6	—
25	3.3	11.4
34—35	3.5	11.3
45	3.1	—

Thus the vertical vibration of the carriage, "shayo-sha," was only about one-third of that of the "kyokuyo-sha." This may be due partly to the difference in the quality of the springs supporting the bodies of the carriages, and partly to the nature of the soil of the districts through which the Sanyo and Tōkaidō Railways are laid.

LATERAL VIBRATION OF THE CARRIAGE.

[On the ground.]

6. Tables VI and VII give respectively for the down and up trains the velocity, and the $2a$ and T of the maximum lateral vibration of the "shayo-sha" at the different distances of the railway, between Kobe and Okayama; the displacements of the carriage produced by a *curve* or a *point* being marked by the letters C and P respectively. (Illustrative diagrams are given in Pls. V and VI.)

TABLE VI. LATERAL VIBRATION OF THE CARRIAGE, "SHAYŌ-SHA." DOWN TRAIN. SANYO RAILWAY.

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
Starts from Kobe.	—	33.0(P)	—
$\frac{1}{2}$	20	4.0	0.41
$\frac{3}{4}$	25	19.0 4.0 …	1.52 0.44
1	18	4.4	0.44
$1\frac{0.5}{4}$	16	4.0	0.51
"	14	5.0	0.44
Starts from Hyogo.	—	(Small.)	0.39
$1\frac{1}{4}$	(Slow.)	4.0	0.44
	18	3.6	0.58
	19	3.4	0.50
$1\frac{1}{2}$	20	3.6	0.40
	21	3.2	0.44
$1\frac{3}{4}$	22	3.8	0.44
2	21	4.6	0.58
	22	3.8	0.47
	24	3.9	0.47
	25	5.6 2.0 …	1.10 0.32
	26--27	3.0	0.78

(Till velocity = 27 miles per hour there predominated short-period vibrations. But, hereafter, slow-period movements became more marked.)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
$2\frac{1}{4}$	28	8.0	1.10
	30	18.4	1.28
	31	9.0	1.24
$2\frac{1}{2}$	33	18.0	1.13
	32	34.0	1.90
$2\frac{3}{4}$	32	22.0	1.50
3	33	25.0 4.0 … Small.	1.53 0.73 0.31

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
Takatori Station.	—	—	—
$3\frac{1}{4}$	35	30.0	2.10
$3\frac{1.5}{4}$	$35\frac{1}{2}$	25.0	0.77
$3\frac{1.5}{2}$	36	11.0 23.0 …	0.73 —
$3\frac{3}{4}$	36	11.0 15.0 25.0	0.84 1.13 (C)
	35	21.0	(C)
	35	21.0	(C)
	32	8.4	1.02
Suma St.	28	3.0	0.40
$4\frac{3}{4}$	27	58.0 69.0 …	(C)
5	29	20.0	(C)
$5\frac{1}{4}$	32	21.0	1.10
	33	5.6 36.0	0.73 (C)
$5\frac{1}{2}$	34	9.6	1.02
$5\frac{3}{4}$	34	10.0	1.02
6	38	26.0	(C)
	39	15.0	0.93
$6\frac{1}{4}$	40	8.0	0.92
	40	42.0 33.0	(C)
Shioya St.	—	—	—
$6\frac{1}{2}$	40	11.0	1.10
$6\frac{3}{4}$	40	11.0 16.0 …	0.95 (C)
7	40	145.0	(C)
$7\frac{1}{4}$	40	3.6	0.55
$7\frac{1}{2}$	39	12.0 35.0 …	0.84 (C)
$7\frac{1.5}{2}$	40	44.0	(C)

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.		Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec)			$2a$ (mm)	T (sec.)
$7\frac{3}{4}$	41	34.0	1.10	$14\frac{1.5}{4}$	36	12.0	1.10
$7\frac{3}{4}$	42	50.0	(*C*)	$14\frac{1}{2}$	37	22.0	(*C*)
8	43	32.0	1.17	$14\frac{1}{2}$	38....	27.0 35.0 4.0	1.24 — 0.51
Tarumi St.	42	102.0 15.0	(*P*) 0.91				
$8\frac{1}{4}$	42	13.0	1.24				
$8\frac{3}{4}$	39	26.0	(*C*)	$14\frac{3}{4}$	$38\frac{1}{2}$	37.0	1.86
$9\frac{1}{4}$	42	23.0	0.80	$14\frac{3.5}{4}$	39	28.0	—
				15	39....	18.0 8.0	— 0.80
Maiko St.	42	44.0	(*P*)	$15\frac{1}{4}$	40	17.0	0.95
	$41\frac{1}{2}$	30.0	1.10				
	41	50.0	(*C*)	$15\frac{1.5}{4}$	42	14.0	1.02
	40	11.0	0.73				
$10\frac{1}{2}$	39	18.0	1.06	$15\frac{1}{2}$	41	14.0	1.06
$10\frac{1.5}{2}$	$39\frac{1}{2}$	112.0	(*C*)				
				$15\frac{3}{4}$	38	7.0	0.51
					39	24.0	1.17
$10\frac{3.5}{4}$	$40\frac{1}{2}$	22.0	1.06	$15\frac{3}{4}$	35....	89.0 110.0	(*C*)
11	41	14.0	0.73	Ōkubo St.	32	50.0	(*P*)
$11\frac{1}{4}$	42	52.0	(*C*)	16	32	42.0	1.75
$11\frac{1.5}{2}$	$42\frac{1}{2}$	10.0	0.78				
$11\frac{3.5}{4}$	44	17.0	0.88	$16\frac{0.5}{4}$	30	31.0	1.10
				$16\frac{1}{4}$	36	88.0	(*C*)
Akashi St.	44	56.0 90.0	(*P*)	$16\frac{1}{2}$	37	58.0	(*C*)
$12\frac{1}{4}$	44	16.0	1.06		38	21.0	0.91
$12\frac{3}{4}$	43	21.0	0.95	$16\frac{3}{4}$	39	18.0	0.91
					$39\frac{1}{2}$	28.0	1.10
$13\frac{1}{2}$	33	8.4	0.88				
14	33	22.0	1.17	17	40....	32.0 27.0	1.02 (*C*)
$14\frac{1}{4}$	35	35.0	(*C*)	$17\frac{1.5}{2}$	41....	34.0 26.0	0.73 (*C*)

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$17\frac{3}{4}$	40	31.0	1.10 (C)
18	38	28.0 8.0	1.10 0.62
$18\frac{1}{4}$	39	23.0 10.0	1.13 0.77
$18\frac{1}{2}$	41	9.0	0.77
$18\frac{1.5}{2}$	43	17.0	0.80
$18\frac{3}{4}$	$43\frac{1}{2}$	63.0 63.0	(C)
	45	37.0	1.46
$18\frac{3.5}{4}$	46	32.0	1.10
19	$46\frac{1}{2}$	34.0	—
$19\frac{1.5}{4}$	47	25.0 13.0	0.98 0.73
$19\frac{1}{2}$	42	11.0	0.69
$19\frac{1.5}{2}$	40	11.0	0.69
$19\frac{3.5}{4}$	38	24.0	1.28
Tsuchi-yama St.	36 35	60.0 66.0	—
$20\frac{0.5}{4}$	34	68.0 (1st mot.) 110.0 (2nd mot.)	2.90 (P)
$20\frac{1}{4}$	36	(Superposed with small vib. of period 0.23 sec.)	
$20\frac{1.5}{4}$	38	17.0 7.0	1.10 0.69
$20\frac{3}{4}$	39	17.0 27.0 27.0 29.0	0.88 (C) (C) (C)
21	40	14.0	0.77

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$21\frac{1}{4}$	40	13.0	0.55
$21\frac{1}{2}$	41	24.0	1.02
$21\frac{3}{4}$	43	23.0	0.84
22	44	23.0	0.91
$22\frac{0.5}{4}$	45	22.0	0.88
$22\frac{1.5}{4}$	47	34.0	(C)
$22\frac{1}{2}$	47	27.0	0.89
$22\frac{3}{4}$	48	16.0 31.0 28.0	0.77 — —
23	46	10.0 22.0 39.0	0.67 — —
$23\frac{1}{4}$	$48\frac{1}{2}$	36.0 25.0	(C) 0.84
$23\frac{1}{2}$	50	15.0 26.0	0.69 0.59
$23\frac{3.5}{4}$	49	25.0	0.89
24	47	21.0	0.88
Kakogawa Station.	46	73.0 (1st mot.) 135.0 (2nd mot.) 48.0	— 2.90 (P)
$24\frac{1}{4}$	45	28.0	1.46
$24\frac{1}{2}$	43	30.0	0.80
$24\frac{3}{4}$	40	34.0	—
Kakogawa Bridge.	38	24.0 18.0 8.0	0.84 0.55 0.47

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
$25\frac{1}{4}$	41	109.0	(C)
(This displacement, which was a single ampl. was executed in 0.91 sec.)			
$25\frac{1.7}{4}$	45	40.0····	(C)
$25\frac{1}{2}$	45····	34.0 16.0····	1.46 0.73
$25\frac{3}{4}$	46····	46.0 45.0····	— 1.50
26	$46\frac{1}{2}$··	24.0 20.0····	0.91 0.73
Murodono Station.	47····	37.0 46.0···· 15.0	(P) (P) 0.77
$26\frac{3}{4}$	48····	46.0 6.0····	1.82 0.47
27	48	26.0	1.10
$27\frac{1.5}{4}$	48	24.0	0.91
$27\frac{1}{2}$	48	110.0	(C)
$27\frac{3.5}{4}$	48	34.0	1.15
28	48····	36.0 47.0···· 30.0	0.80 0.77
$28\frac{1}{4}$	45	19.0	1.09
$28\frac{1.5}{4}$	42	12.0	0.88
$28\frac{1}{2}$	39.5	13.0	0.84
$28\frac{3}{4}$	39	7.0	0.64
Sone St.	40	51.0	1.28 (P)
$29\frac{1}{4}$	39····	31.0 13.0····	1.31 0.88
$29\frac{1}{2}$	$38\frac{1}{3}$····	40.0 64.0····	(C)
$29\frac{3}{4}$	$36\frac{1}{2}$	22.0	0.99

Distance from Kobe. (miles)	Velocity. mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
$29\frac{3.5}{4}$	$38\frac{1}{2}$	52.0	1.31
30	39	16.0	0.91
$30\frac{0.5}{4}$	40	48.0	2.20
$30\frac{1}{4}$	40	7.0	0.95
$30\frac{1}{2}$	40	15.0	0.99
$31\frac{0.5}{4}$	$39\frac{1}{2}$	20.0	0.95
Gochiaku Station.	40····	73.0 51.0	(P)
$31\frac{3}{4}$	40····	43.0 22.0····	— 0.99
$32—32\frac{1.5}{4}$	40—39··	66.0 80.0 80.0···· 11.0	(C) (C) (C) 0.77
$32\frac{1.5}{4}$–$32\frac{3}{4}$ (Bridge.)	38—39··	5.0 3.0···· 28.0	0.51 0.23 1.24
33	40	13.0	0.80
$33\frac{1}{4}$	39	6.0	0.58
$33\frac{1}{2}$	38	15.0	0.95
$33\frac{1.5}{2}$	36····	7.0 18.0····	0.80 1.50
$33\frac{3}{4}$	34	9.0	0.73
$33\frac{3.5}{4}$	27—22··	12.0 6.0····	1.46 0.55
34	19	5.0	0.53
	15····	10.0 2.0····	0.58 0.36
Arrives at Himeji St.	—	—	—

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
Starts from Himeji St.	—	—	—
	15	4.0	0.55
$34\frac{1}{4}$	18	4.0	0.58
	$20\frac{1}{2}$	8.0 4.5	0.69 0.44
	$22\frac{1}{2}$	8.0	0.44
$34\frac{1.5}{4}$	24	4.0	0.40
$34\frac{1}{2}$	26	11.0	1.06
(Hereafter slower vibrations predominate.)			
	27	11.0 3.0	1.10 0.40
	28	19.0	1.75
$34\frac{3}{4}$	$30\frac{1}{2}$	15.0	1.46
	31	8.0	0.77
(Hereafter vibrations of this kind become predominating.)			
$34\frac{3}{4}$	32	12.0	0.77
	33	13.0	0.95
	34	10.0	0.95
35	35	6.0	0.55
	$36\frac{1}{2}$	21.0	1.06
$35\frac{1}{4}$	37	20.0	0.88
	38	26.0	0.95
(Hereafter the motion becomes more violent.)			
	39	20.0	0.89
$35\frac{1}{2}$	40	35.0	0.85
$35\frac{1.5}{2}$	40	20.0	0.77
$35\frac{3}{4}$	40	21.0	0.77
$35\frac{3.5}{4}$	41	34.0 56.0	— 1.53
36	42	9.0	0.77
36	43	26.0	0.73
$36\frac{1}{4}$	44	19.0	0.58
	45	20.0	0.73
$36\frac{1}{2}$	46	27.0	0.80
$36\frac{3}{4}$	47	14.0	0.69
$36\frac{3.5}{4}$	$46\frac{1}{2}$	23.0 15.0 34.0	0.69 0.62
37	46	43.0 30.0 40.0 47.0	(C) 0.73 0.73 0.88
$37\frac{1}{4}$	45	80.0 (1st displ.) 140.0 (2nd displ.)	1.8 (C)
		86.0 (1st displ.) 133.0 (2nd displ.)	—
	43	15.0	0.73
$37\frac{1}{2}$ (Bridge.)	42	28.0 7.0	1.02 0.69
	43	19.0	0.91
$37\frac{3}{4}$	44	28.0	0.73
	46	20.0	0.95
38	48	33.0 34.0	— 0.66
	$48\frac{1}{2}$	24.0	0.92
		33.0	(C)
		47.0	(C)
$38\frac{1}{4}$	49	27.0	0.62
$38\frac{1}{2}$	49	40.0 41.0 24.0	— — 0.69

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. 2a (mm)	Maximum vibration. T (sec.)
$38\frac{1.5}{2}$	49....	18.0 18.0	0.73 0.93
$38\frac{3}{4}$	49	32.0	0.58
		43.0	(*C*)
$38\frac{3.5}{4}$	49....	66.0 40.0 .... 68.0	0.95 (*C*) 0.88 (*C*)
39	$48\frac{1}{2}$	32.0	0.69
		40.0	0.69
	48....	27.0 39.0	0.55 0.69
$39\frac{1}{4}$	43	100.0	(*C*)
	45	16.0	0.55
	44	11.0	0.47
$39\frac{1}{2}$	43	9.0	0.51
	42....	9.0 14.0	0.55 0.95
$39\frac{3}{4}$	$40\frac{1}{2}$	12.0	0.66
	38	8.0	0.62
		11.0	0.69
40	37	10.0	0.77
	36....	6.0 15.0	0.69 1.39
$40\frac{1}{4}$	35	16.0	1.28
$40\frac{1.5}{4}$	33....	152.0 (1st displ.) 132.0 (2nd displ.)	(*P*)
Aboshi St.	32	14.0	1.10
$40\frac{1}{2}$	31....	95.0 (1st displ.) 180.0 (2nd displ.)	(*P*)
	30....	7.0 1.2	0.73 0.29

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. 2a (mm)	Maximum vibration. T (sec.)
$40\frac{3}{4}$	31....	10.0 2.5	1.02 0.26
41	33	21.0	1.39
	35	34.0	(*C*)
$41\frac{1}{4}$	36	12.0	0.80
	37	8.0	0.73
$41\frac{1}{2}$	38	9.0	0.66
		22.0	—
$41\frac{3}{4}$	39	26.0	—
		18.0 7.0	1.02 0.62
	38	15.0	0.88
42	$37\frac{1}{2}$	26.0	—
	37	14.0	0.92
	$37\frac{1}{2}$	12.0	0.91
$42\frac{1}{4}$	38	49.0	(*C*)
	38	18.0	0.84
$42\frac{1}{2}$	37....	106.0 60.0	(*C*)
	35	9.0	0.80
	32	14.0	1.64
$42\frac{3}{4}$	30	13.0	1.90
	29	2.0	0.29
	28....	10.0 2.5	1.42 0.22
43	27....	7.0 2.5	0.95 0.36
	28	7.0	0.95
	29....	2.8 14.0	0 42 1.64
	30	2.0	0.33
$43\frac{1}{4}$	31	48.0	(*C*)

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. 2a (mm)	Maximum vibration. T (sec.)
		44.0	1.86
$43\frac{1}{4}$	30	19.0	1.28
$43\frac{1}{2}$	29	7.0	0.73
(Bridge.)	30....	{ 13.0 / 6.0	{ 0.95 / 0.62
$43\frac{3}{4}$	31....	{ 12.0 / 2.5	{ 0.91 / 0.36
	32	12.0	0.91
	$33\frac{1}{2}$..	{ 7.0 / 2.5	{ 0.62 / 0.36
44	34....	{ 90.0 / 64.0	2.40(*P*)
Tatsuno Station.	34....	{ 14.0 / 4.0	{ 1.13 / 0.73
$44\frac{1}{4}$	34....	{ 76.0 (1st displ.) / 140.0 (2nd displ.)	2.70(*P*)
	35....	{ 10.0 / 4.0	{ 0.77 / 0.58
$44\frac{1}{2}$	36	12.0	1.10
	$36\frac{1}{2}$	30.0	1.06
	37....	{ 36.0 / 12.0	{ 1.29 / 0.88
$44\frac{3}{4}$	37....	{ 13.0 / 23.0 .... / 40.0	{ 0.95 / — / —
45	35....	{ 44.0 / 21.0	{ — / 1.10
$45\frac{1}{4}$	35....	{ 53.0 / 58.0	(*C*)
$45\frac{1}{2}$	—	46.0	(*C*)
46	41....	{ 96.0 / 102.0 .... / 102.0	{ (*C*) / (*C*) / 2.70 (*C*)
$46\frac{3}{4}$	34	76.0	(*P*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. 2a (mm)	Maximum vibration. T (sec.)
Nawa St.	—	—	—
$47\frac{1}{2}$	34....	{ 82.0 (1st displ.) / 92.0 (2nd displ.)	(*P*)
$50\frac{1.3}{2}$	36....	{ 118.0 / 64.0	{ (*C*) / (*C*)
$51\frac{1}{2}$	38	(Small)	(*P*)
Aritoshi St.	—	—	—
$51\frac{3}{4}$	38	100.0	1.68 (*P*)
$52\frac{0.6}{4}$	—	78.0	(*C*)
$52\frac{1.5}{4}$	38....	{ 117.0 / 125.0	{ 2.40 / 2.60
$53\frac{0.4}{4}$–$53\frac{1.5}{2}$	42....	{ 59.0 (1st displ.) / 118.0 (2nd displ.) / 94.0	(*C*) / (*C*) / (*C*)
{ Arrives at Kamigori.			
{ Starts from Kamigori. (motion became more pronounced at about vel.=15 miles per hour.)			
	15	3.0	0.44
	17	5.0	0.51
	18	7.0	0.61
	19	8.0	0.58
	20	9.0	0.49
	21	4.0	0.36
	22	4.0	0.42
56	22	6.0	0.44
$56\frac{1}{4}$	22	6.0	0.50
$56\frac{3}{4}$	$28\frac{1}{2}$	4.0 / 58.0	0.84 / 2.30

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
57	29	14.0	1.24
		6.0	0.95
$58\frac{1}{4}$	25	12.0	1.17
		2.5	0.35
	24	3.0	0.36
59	23	4.5	0.36
$59\frac{1}{2}$	$22\frac{1}{2}$	4.5	0.44
60	22	6.0	0.47
$60\frac{1}{2}$	$21\frac{1}{2}$	4.5	0.44
$61\frac{1}{4}$	21	6.0	0.40
$61\frac{1}{2}$	$20\frac{1}{5}$	7.5	0.52
62 (In tunnel)	20	5.2	0.55
	21	5.2	0.44
	22	5.0	0.40
	23	7.0	0.51
	23	5.0	0.44
(So far the motion consisted of regular small vibrations of short period.)			
$62\frac{3}{4}$	27	4.0	0.47
	28	4.0	0.73
	29	4.0	0.69
	30	9.5	0.73
63	31	7.0	0 95
	32	5.0	0.88
	33	6.0	0.73
$63\frac{1}{4}$	34	280	(*C*)
	$33\frac{1}{2}$	6.0	0.69
	33....	28.0	(*C*)
		5.5....	0.73
		3.0	0.40

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$63\frac{1}{2}$	32	86.0 (1st displ.)	2.20(*P*)
		94.0 (2nd displ.)	
Mitsuishi Station.	31....	114.0....	(*P*)
	30	18.0	0.88
$63\frac{3}{4}$	29....	114.0....	(*C*)
		165.0	
	30	5.0	0.55
	31	48.0	2.40
64	39	28.0	1.83
$64\frac{1}{4}$	37....	112.0....	2.30 (*C*)
		95.0	2.20 (*C*)
	36....	109.0....	(*C*)
		102.0	(*C*)
$64\frac{1}{2}$	39....	12.0....	0.95
		8.0	0.58
$64\frac{3}{4}$	41	10.0	0.73
	42	13.0	0.77
65	$42\frac{1}{2}$	146.0	(*C*)
	43	24.0	1.20
$65\frac{1}{4}$	44	90.0	(*C*)
	$44\frac{1}{2}$	13.0	0.80
	45	28.0	0.80
$65\frac{1}{2}$	46	26.0	0.77
	$46\frac{1}{2}$	21.0	0.95
	47....	21 0....	0.84
		10.0	0.77
$65\frac{3}{4}$	$47\frac{1}{2}$	96.0	(*C*)
66	$49\frac{1}{2}$	164.0	(*C*)

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$66\frac{1}{4}$	50	144.0	(C)
		36.0	0.77
$66\frac{1}{2}$	51....	26.0 107.0	0.73 (C)
$66\frac{3}{4}$	$51\frac{1}{2}$	121.0	(C)
$66\frac{3.5}{4}$	$51\frac{1}{2}$	122.0	(C)
67	52	150.0	(C)
	52....	32.0 18.0	1.10 0.77
$67\frac{1}{4}$	52	13.0	0.66
		47.0	—
	50	18.0	0.73

(Between $67\frac{1}{2}$ and $67\frac{1.5}{2}$ miles, there were slow large vibrations due to *curves*.)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$67\frac{3}{4}$	41	12.0	0.73
	$40\frac{1}{2}$	13.0	0.88
	$39\frac{1}{2}$	8.0	0.62
68 Yoshinaga Station.	39	76.0 (1st displ.)	(P)
	38	152.0	—
	37	13.0	1.24
	36....	68.0 (1st displ.) 106.0 (2nd displ.)	(P)
$68\frac{1}{2}$	36....	5.0 17.0	0.51 0.99
	37	8.0	0.95
	38	6.0	0.73
$68\frac{3}{4}$	$39\frac{1}{2}$	10.0	1.10
	41	10.0	0.55

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
69	$44\frac{1}{4}$	10.0	0.77
	$43\frac{1}{2}$	22.0	0.99
$69\frac{1}{2}$	41	9.0	0.73
$69\frac{3}{4}$	39	9.0	1.00
70	40	52.0	(C)
$70\frac{1}{4}$ (On bridge.)	$39\frac{1}{2}$..	16.0 21.0	0.91 1.02
$70\frac{1}{2}$	40	9.0	0.84
	41	16.0	0.92
$70\frac{3}{4}$	42	11.0	0.84
71	41	6.0	0.73
	40	14.0	0.73
	36	8.0	0.88
$71\frac{1}{4}$	34....	65.0 (1st displ.) 144.0 (2nd displ.)	(P)
Wage St.	32		
$71\frac{1}{2}$	31	86.0	(P)
$71\frac{3}{4}$	32	7.0	0.73
	33	7.0	0.73
72	35	117.0	(C)
$72\frac{1}{4}$	37	15.0	0.80
$72\frac{1}{2}$	39	29.0	1.50
	$39\frac{1}{2}$	24.0	0.88
$72\frac{3}{4}$	42	25.0	1.06
73	43....	118.0 18.0	2.10 1.10
$73\frac{1}{4}$	44....	60.0 55.0	(C) (C)
		16.0	1.13

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Miximum vibration. 2a (mm)	T (sec.)
$73\frac{1}{2}$	45	14.0	0.84
$73\frac{3}{4}$	46	136.0	(*C*)
74	47	138.0	(*C*)
	47	26.0	0.91
$74\frac{1}{4}$	$47\frac{1}{2}$	18.0	0.84
$74\frac{1}{2}$	48	93.0	(*C*)
		27.0	0.88
$74\frac{3}{4}$	49	21.0	0.95
75	50	21.0	0.73
$75\frac{1}{4}$	50....	{ 34.0 18.0	{ 1.17 0.88
$75\frac{1}{2}$	$49\frac{1}{2}$	10.0	0.73
$75\frac{3}{4}$	48....	{ 79.0 (1st displ.) 156.0 (2nd displ.)	(*C*) (*C*)
76 (On bridge)	{ 42 41	{ 120.0 22.0	2.20 (*C*) 0.88
Mantomi Station.	33	6.0	0.80
	32	{ 132.0 (1st displ.) 144.0 (2nd displ.)	(*P*)
77	33	9.0	0.80
	34	10.0	0.84
$77\frac{1}{4}$	$35\frac{1}{2}$	22.0	0.95
$77\frac{1}{2}$	36	10.0	0.62
	37	26.0	0.95
$77\frac{3}{4}$	38	20.0	0.88
	$37\frac{1}{2}$	47.0	1.21
78	37	17.0	1.02

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. 2a (mm)	T (sec.)
$78\frac{1}{4}$	34....	{ 47.0 19.0	{ 1.50 1.10
$78\frac{1}{2}$	36....	{ 4.0 11.0	{ 0.55 0.73
$78\frac{3}{4}$	$39\frac{1}{2}$..	{ 7.0 31.0	{ 0.73 1.17
79	42	15.0	0.88
$79\frac{1}{4}$	37	7 0	0.58
	35....	{ 86.0 (1st displ.) 167.0 (2nd displ.)	(*P*)
Seto St.	34	8.0	0.55
	$32\frac{1}{2}$	128.0	(*P*)
$79\frac{3}{4}$	32	6.0	0.73
	31	56.0	2.20
80	31	14.0	0.69
	$32\frac{1}{2}$	9.0	0.84
$80\frac{1}{4}$	$34\frac{1}{2}$	28.0	1.10
	$39\frac{1}{2}$	13.0	0.95
$80\frac{1}{2}$	42	26.0	1.06
	43	18.0	0.77
	44	17.0	0.62
	45....	{ 40.0 22.0	{ 0.80 0.73
81	45	19.0	0.69
$81\frac{1}{4}$	45	(Record wanting, probably a *curve* effect.)	
$81\frac{1}{2}$	46	112.0	(*C*)
$82\frac{1}{4}$	47	28.0	0.95
$82\frac{1}{2}$	48	12.0	0.73

TABLE VI. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. 2a (mm)	Maximum vibration. T (sec.)
$82\frac{3}{4}$	50...	{ 27.0 24.0 ...	1.28 0.80
83	$49\frac{1}{2}$	22.0	0.73
	49	28.0	0.80
$83\frac{1}{2}$	47	13.0	0.58
	46	20.0	0.73
	$44\frac{1}{2}$	10.0	0.73
$83\frac{3}{4}$	43	19.0	0.88
84	41	9.0	0.55
$84\frac{1}{4}$	38....	{ 63.0 65.0 ...	(*C*) (*C*)
	$36\frac{1}{2}$	14.0	0.91
Nagaoka St.	34	10.0	0.73
$84\frac{3}{4}$	33	17.0	0.80
		42.0	—
	34	13.0	0.95
$85\frac{1}{4}$	35	7.0	0.69
		11.0	1.17
$85\frac{3}{4}$	37	12.0	1.10
		16.0	1.10
$85\frac{3}{4}$		10.0	0.77
$86\frac{1}{4}$	38	13.0	1.06
$86\frac{1}{2}$	39 ...	{ 20.0 8.0 ...	{ 1.24 0.73
$86\frac{3}{4}$	38....	{ 12.0 20.0 ...	{ 0.80 1.35
87	37	72.0	(*C*)
(On bridge.)	38....	{ 6.0 16.0 ...	{ 0.73 1.46
$87\frac{1}{4}$	39	16.0	1.10
	40	26.0	0.98
$87\frac{1}{2}$	$39\frac{1}{2}$	70.0	(*C*)
(On bridge.)	37	17.0	0.80
88	$37\frac{1}{2}$	{ 86.0 (1st displ.) 122.0 (2nd displ.)	(*C*)
$88\frac{3}{4}$	37	11.0	0.80
	35	5.0	0.69
	33	8.0	0.73
$88\frac{3.7}{4}$	27....	{ 86.0 (1st displ.) 160.0 (2nd displ.)	(*P*)
89	20	2.5	0.41
	15	4.0	0.44
Arrives at Okayama.			

TABLE VII. LATERAL VIBRATION OF THE CARRIAGE, "SHAYO-SHA." UP TRAIN. SANYO RAILWAY.

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
Okayama Station. 89	15	4.8	0.69
	16	5.6	0.55
	$17\frac{1}{2}$	8.3	0.55
	18	7.0	0.55
	19	4.5	0.46
	$19\frac{1}{2}$	8.2	0.58
$88\frac{3}{4}$	21	7.0	0.47
	22	8.0	0.47
	23	6.0	0.47
	$23\frac{1}{2}$	(Here was a *point*, but no effect was produced.)	
$88\frac{1}{2}$	24	4.0	0.40
	25 ····	{ 10.0 ···· 6.0	{ 1.09 0.44
$88\frac{1}{4}$	24 ····	{ 7.0 ··· 5.0	{ 0.95 0.40
88	$23\frac{1}{2}$	4.2	0.40
	22	4.2	0.44
$87\frac{3}{4}$	23	6.0	0.54
	24	4.0	0.40
	25	54.0	(*C*)
	26	21.0	1.68
	27 ····	{ 14.0 ···· 4.2	{ 1.13 0.52
	29	2.0	0.22
$87\frac{1}{2}$	32 ····	{ 4.0 ··· 32.0	{ 0.55 (*C*)
	34	(Hereafter motion becomes much stronger.)	
	34	19.5	1.20
	35	32.0	1.64

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
$87\frac{1}{2}$	34	29.0	1.09
$87\frac{1}{4}$	35	54.0	
87	35 ····	{ 180.0 ···· 136.0	3.10
	$37\frac{1}{2}$	14.0	1.09
$86\frac{3}{4}$	39	17.5	0.88
	40	25.0	1.17
	41	10.0	0.73
$86\frac{1}{2}$	42	17.0	0.91
86	41	19.0	1.02
$85\frac{3}{4}$	40	17.0	1.09
$85\frac{1}{2}$	38	8.0	0.73
$85\frac{1.5}{4}$	$37\frac{1}{2}$	19.0	
$85\frac{1}{4}$	37	13.0	0.95
	36	13.0	0.84
85	35	12.0	0.88
	34 ···	{ 18.0 ···· 9.5	{ 1.31 1.09
	33	11.0	1.35
$84\frac{3}{4}$	32	84.0	(*P*)
Nagaoka Station.	31 ····	{ 85.0 90.0 106.0	
$84\frac{1}{2}$	30	95.0	(*P*)
	31	18.0	1.17
$84\frac{1}{4}$	32	23.0	1.46

TABLE VII. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
84	34	24.0	
	35	18.0	0.84
	36	7.0	0.55
$83\frac{3}{4}$	37	12.0	0.73
$83\frac{1}{2}$	38	17.0	0.95
$83\frac{1}{4}$	39	22.0	0.73
$83\frac{0.5}{4}$	40	29.0	1.02
83	$40\frac{1}{2}$	27.0	0.73
$82\frac{3}{4}$	41....	{ 32.0 38.0 ...	{ 0.88 0.73
$82\frac{1}{2}$	40	29.0	
		34.6	0.73
$82\frac{1}{4}$	39....	{ 24.0 30.0 ...	1.09 (*C*)
$82\frac{0.5}{4}$	39	70.0	(*C*)
$81\frac{3.5}{4}$	40....	{ 80.0 22.0 ...	{ (*C*) 1.02
$81\frac{3}{4}$	42	48.0	(*C*)
	43	26.0	1.02
$81\frac{1}{2}$	44....	{ 48.0 (1st displ.) 94.0 (2nd displ.) 78.0	(*C*) (*C*) (*C*)
$81\frac{1}{4}$	45	77.0	(*C*)
81	45	29.0	0.77
$80\frac{3}{4}$	44	28.0	0.99
$80\frac{1.5}{4}$	43	102.0	2.90 (*C*)
$80\frac{1}{4}$	41	32.0	0.95
$79\frac{1.5}{2}$	35	62.0	(*P*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
Seto St.	33	10.0	0.73
$79\frac{1.5}{4}$	33....	{ 74.0 (1st displ.) 128.0 (2nd displ.)	(*P*)
$79\frac{1}{4}$	32	46.0	1.82
79	34	32.0	1.17
		18.0	1.64
$78\frac{3.5}{4}$	33....	{ 39.0 32.0 ...	{ 1.31 —
$78\frac{3}{4}$	31	30.0	1.60
	30	34.0	1.09
$78\frac{1.5}{2}$	29	10.0	0.88
$78\frac{1.1}{2}$	29 (Here begins a gradual *curve* deviation, which comes back to original position at $78\frac{1}{4}$ miles; but there was no sudden *curve* effect.)		
$78\frac{1}{2}$	28	6.0	0.44
$78\frac{1.5}{4}$	27	5.0	0.55
$78\frac{1}{4}$	28	26.0	1.38
	31	16.0	0.84
	34	22.0	1.09
78	36	61.0	1.60
$78\frac{1}{2}$	39	26.0	2.10
$78\frac{1}{4}$	$37\frac{1}{2}$	20.0	1.28
	$36\frac{1}{2}$	15.0	1.09
77	35	13.0	1.17
$77\frac{3.5}{4}$	33	49.0	(*P*)
Mantomi Station.	32....	{ 12.0 22.0 ...	{ 0.91 1.97

TABLE VII. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$76\frac{1.5}{2}$	31····	78.0 (1st displ.) 165.0 (2nd displ.)	(*P*)
76	28	37.0	1.75
	29	79.0	2.26
	31	29.0	1.82
$75\frac{3}{4}$	34····	56.0 (1st displ.) 118.0 (2nd displ.)	(*C*)
$75\frac{1.5}{4}$	37	27.0	1.09
$75\frac{1}{4}$	39	27.0	1.64 (*C*)
75	40	23.0	0.88
$74\frac{1}{2}$	40····	44.0 ···· 70.0	1.09 (*C*)
$74\frac{1}{4}$	41	22.0	1.06
$74—73\frac{3.5}{4}$	42····	80.0 (1st displ.) 116.0 (2nd displ.) 150.0 "	(*C*) 2.20 (*C*)
$73\frac{1.5}{2}$	$42\frac{1}{2}$	11.0	0.88
$73\frac{1.1}{2}$	43	78.0	(*C*)
$73\frac{1}{4}$	$43\frac{1}{2}$··	105.0 ···· 16.0	(*C*) 0.66
$72\frac{1}{2}$	44	113.0	(*C*)
	$43\frac{1}{2}$	21.0	0.84
$72\frac{0.3}{4}$	41	102.0	2.80 (*C*)
$72\frac{0.5}{4}$	40	128.0	(*C*)
72	39	100.0	2.80 (*C*)
$72\frac{3.5}{4}$	38	15.0	0.87
	37	8.0	0.73
$71\frac{1}{2}$	34	79.0	(*P*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
Arrives at Wage.	—	—	—
$71\frac{0.5}{4}$	20	4.0	0.55
71	22	4.0	0.40
	$23\frac{1}{2}$	5.0	0.42
$70\frac{3}{4}$	23	4.0	0.42
$70\frac{1}{2}$	23	5.0	0.51
On bridge.	24	5.0	0.36
	$25\frac{1}{2}$	5.0	0.40
70	27	10.0	1.09
$69\frac{3}{4}$	26	3.6	0.36
On bridge.	27····	4.0 ···· 2.0	0.66 0.26
$69\frac{1}{2}$	30	6.0	0.95
	33	4.5	0.73
$69\frac{1.5}{4}$	34	21.0	1.40
$69\frac{1}{4}$	35	8.0	0.91
69	34	10.0	0.76
$68\frac{1}{2}$	$33\frac{1}{2}$	11.0	1.09
On bridge.	32····	5.0 ···· 2.0	0.55 0.22
$68\frac{1}{4}$	30	2.0	0.29
$68\frac{0.5}{4}$	30	56.0	(*P*)
Yoshinaga Station.	29	7.0	0.73
	28····	67.0 (1st displ.) 107.0 (2nd displ.)	(*P*)
$67\frac{3}{4}$	$27\frac{1}{2}$	3.0	0.40
$67\frac{1.5}{4}$	25	4.0	0.33

TABLE VII. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
$67\frac{1}{4}$	27	17.0 7.0 3.0	1.30 0.91 0.44
$66\frac{1.5}{2}$	27	40.0	(*C*)
$66\frac{1.5}{4}$	$26\frac{1}{2}$	3.0 15.0	0.54 1.46
$66\frac{1.3}{4}$	$26\frac{1}{2}$	(Curve, but no sudden displacement.)	
$66\frac{0.5}{4}$	$25\frac{1}{2}$	72.0	(*C*)
$65\frac{1}{2}$	24	6.0	0.55
$65\frac{1}{4}$	$23\frac{1}{2}$	4.0	
(Here begins a *curve*, but no particular displacement was produced.)			
$64\frac{3.5}{4}$	23		
(Here ends the *curve*, but no special displacement was produced.)			
$64\frac{3}{4}$	23	6.5	0.40
On bridge.	23	3.0 3.0	0.29 0.36
$64\frac{1}{2}$	$22\frac{1}{2}$	5.0	0.40
$64\frac{1}{2}-\frac{1}{4}$	(Curve; but no displacement.)		
$63\frac{3.5}{4}$	22	5.0	0.40
$63\frac{3}{4}$	21	3.0	0.44
	19	3.0 6.0	0.44 0.73
Arrives at Mitsuishi St.	—	—	—
$63\frac{1}{2}$	15	5.0	0.55

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. $2a$ (mm)	Maximum vibration. T (sec.)
$63\frac{0.5}{4}$	17	6.5	0.62
$62\frac{3.5}{4}$	18	5.2	0.62
$63\frac{3}{4}$	$18\frac{1}{2}$	4.5	0.47
Tunnel.	19	9.0	0.55
	$19\frac{1}{2}$	7.0	0.55
	20	3.8	0.51
	21	4.0	0.47
	$22\frac{1}{2}$	4.0	0.40
	23	4.5	0.40
	$23\frac{1}{2}$	6.0	0.55
	24	4.0	0.55
	25	11.0	1.02
$61\frac{3}{4}$	27	8.0	0.66
	29	52.0	(*C*)
	30	7.0	0.77
	31	9.0	0.77
$61\frac{1}{2}$	32	18.0	(*C*)
	33	7.0	0.73
	34	11.0	0.80
$61\frac{1}{4}$	35	21.0	1.10
	36	26.0	0.88
$61\frac{0.8}{4}$	$36\frac{1}{2}$	56.0	(*C*)
$60\frac{3}{4}$	40	74.0	(*C*)
$60\frac{1.5}{2}$	$41\frac{1}{2}$	33.0	0.84
$60\frac{1}{2}$	42	23.0	0.88
	43	23.0	0.80

TABLE VII. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.		Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)			$2a$ (mm)	T (sec.)
$60\frac{1}{4}$	44	32.0	0.77	$55\frac{1.3}{2}$	15	4.0	0.55
	45	33.0	0.77	$55\frac{1}{2}$	18	6.0	0.54
$60\frac{0.5}{4}$	$45\frac{1}{2}$	73.0	(C)		20	6.0	0.51
$59\frac{3.4}{4}$	47	116.0	(C)		21	5.0	0.55
$59\frac{1}{2}$	48	109.0	2.30 (C)	$55\frac{1}{4}$	$23\frac{1}{2}$	6.0	0.36
		122.0	(C)		24	6.0	0.44
		11.0	0.55		25	8.0	0.40
$59\frac{1}{4}$	$48\frac{1}{2}$	103.0	(C)		26	5.0	0.44
					27····	11.0 3.5	0.73 0.40
59	50····	15.0 115.0	0.73 1.53 (C)		30····	18.0 9.0	1.10 0.88
$58\frac{3}{4}$	51····	85.0 144.0	1.39 (C) (C)	$54\frac{3}{4}$	$32\frac{1}{2}$	17.0	1.02
$58\frac{1.5}{2}$	52	23.0	0.69	$54\frac{1.5}{2}$	35	72.0	(C)
$58\frac{1.6}{4}$	53	108.0	(C)	$54\frac{1.5}{4}$	39	51.0	1.35
$58\frac{1}{4}$	54	24.0	0.73	$54\frac{1}{4}$	$41\frac{1}{2}$	19.0	0.73
$57\frac{3.5}{4}$	50	128.0	(C)		42	26.0	1.17
$57\frac{1.4}{4}$	50	132.0	(C)	$54\frac{0.5}{4}$	43	16.0	0.73
						94.0	(C)
$56\frac{3}{4}$	50	80.0	(C)	54	44	58.0	1.57
$56\frac{1.5}{4}$	49····	114.0 120.0	(C)	$53\frac{1.5}{2}$	$45\frac{1}{2}$	30.0	0.80
On bridge.	48	11	0.77	$53\frac{1}{2}$	46····	43.0 81.0	0.84 1.68
$56\frac{0.5}{4}$	45····	15.0 9.0	1.10 0·62				
				$53\frac{0.5}{4}$	44	(A *curve*, but no special displacement.)	
$55\frac{3.3}{4}$	25	56.0	(P)	53	43	22.0	1.09
$55\frac{3}{4}$	20	4.5	0.47	$52\frac{1.5}{2}$	42	24.0	1.02
	20	5.0	0.55				
Arrives at Kami-gōri.	—	—	—	$52\frac{1.5}{4}$	40···	92.0 (1st displ.) 153.0 (2nd displ.)	1.75 (C)

TABLE VII. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$52\frac{0.4}{4}$	38	86.0	(C)
52	37	19.0	0.91
$51\frac{3}{4}$	35....	80.0 (1st displ.) 129.0 (2nd displ.)	(P)
Aritoshi Station	34	104.0	(C)
$51\frac{1}{2}$	32....	96.0 (1st displ.) 106.0 (2nd displ.)	(P)
$51\frac{1.4}{4}$	$30\frac{1}{2}$	30.0	1.53
$50\frac{3}{4}$	32	25.0	1.39
$50\frac{1}{4}$	$34\frac{1}{2}$	59.0	(C)
$49\frac{3.6}{4}$	36	33.0	1.83
$49\frac{3}{4}$	37	19.0	1.02
$49\frac{1}{2}$	36	18.0	1.09
49	38	14.0	0.98
$48\frac{1}{4}$	39	17.0	0.88
$47\frac{3}{4}$	43	87.0	1.90
$48\frac{1}{2}$	44	27.0	1.17
	$43\frac{1}{2}$	43.0	1.13
$47\frac{1.7}{4}$	43	88.0	(C)
Nawa St.	$32\frac{1}{2}$	160.0	3.30
$46\frac{3.5}{4}$	32	154.0	(P)
$46\frac{3.2}{4}$	31	129.0	(C)
$46\frac{1}{2}$	36	33.0	1.17
$46\frac{0.7}{4}$	$34\frac{1}{2}$	(*Curve*, but no special displacement.)	
$45\frac{3}{4}$	35	16.0	0.91
$45\frac{1.5}{4}$	36	68.0	2.00
$44\frac{1.5}{4}$	34	64.0	2.20
$44\frac{1}{4}$	$32\frac{1}{2}$	148.0	(P)
Tatsuno Station.	—	—	—
$44\frac{0.2}{4}$	30	160.0	(P)
$43\frac{1}{2}$ -- $\frac{3}{4}$ (On bridge)	27—30..	2.5... 8.0	0.33 0.73
$43\frac{1}{4}$	35	64.0	1.83
$42\frac{1}{2}$	32	85.0	(C)
$42\frac{1.5}{4}$	34	40.0	1.20
$42\frac{1.3}{4}$	34	(*Curve*, but no strong displacement.)	
$42\frac{1}{4}$	34	12.0	0.88
$41\frac{3}{4}$	39	22.0	0.88
$41\frac{1}{2}$	38	18.0	0.88
41	35	15.0	0.95
$40\frac{3}{4}$ — $\frac{3.7}{4}$	34—35	(No *curve* effect.)	
$40\frac{1.3}{2}$	$33\frac{1}{2}$	25.0	(P)
Aboshi St.	33	25.0	—
$40\frac{1.4}{4}$	33	122.0	(P)

TABLE VII. (*Continued.*)

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$39\frac{3.5}{4}$	37....	{ 25.0 6.0	{1.02 0.55
$39\frac{3}{4}$	38....	{ 53.0 27.0	{1.24 0.66
$39\frac{1.5}{4}$	41	24.0	0.92
$39\frac{1}{4}$	42	146.0	3.00
$39\frac{0.5}{4}$	43	32.0	1.09
$38\frac{3.5}{4}$	44	29.0	0.80
	45	60.0	(*C*)
$38\frac{3}{4}$	46....	{ 65.0 19.0	{1.39 0.69
$38\frac{1}{2}$	$46\frac{1}{2}$	35.0	0.69
$38\frac{0.5}{4}$	$46\frac{1}{2}$	39.0	0.77
38	$46\frac{1}{2}$	30.0	0.73
$37\frac{3.5}{4}$	46	31.0	1.09
$37\frac{1.7}{2}$	44....	{ 12.0 24.0	{0.58 1.17
On bridge.	43....	{ 17.0 6.0 .... 18.0	{0.73 0.55 1.13
$37\frac{1.5}{4}$	44....	{ 25.0 20.0	{0.95 0.69
$37\frac{1.2}{4}$	45....	{ 84.0 (1st displ.) 152.0 (2nd displ.)	2.20 (*C*)
$37\frac{0.5}{4}$	58	130.0	1.9 (*C*)
$37\frac{0.2}{4}$	49	49.0	0.73
	48	34.0	0.84
$36\frac{3.8}{4}$	$49\frac{1}{2}$	36.0	0.91
$36\frac{3}{4}$	50	38.0	0.95
$36\frac{1}{2}$	49	26.0	0.95
$36\frac{1}{4}$	48....	{ 51.0 56.0	(*C*)
36	47	16.0	0.66
$35\frac{3.5}{4}$	$46\frac{1}{2}$..	{ 59.0 34.0 ...	{1.10 0.73
$35\frac{1.5}{4}$	$45\frac{1}{2}$	25.0	0.73
$35\frac{1}{4}$	45	33.0	0.80
35	$44\frac{1}{2}$	26.0	0.91
$34\frac{3.5}{5}$	$43\frac{1}{2}$	26 0	0.95
$34\frac{3.3}{4}$	43	42.0	—
$34\frac{1.5}{2}$	40	52.0	(*C*)
$34\frac{1.5}{4}$	$36\frac{1}{2}$	87.0	2.30
$34\frac{1}{4}$	33	91.0	(*C*)
	27	126.0	(*P*)
{Arrives at Himeji.	—	—	—
$32\frac{3.7}{4}$	15	4.0	0.44
	18	10.0	0.51
	19	6.0	0.55
	20	3.0	0.40
	22	3.0	0.40
$32\frac{3}{4}$	23	4.0	0.33
	$24\frac{1}{2}$	4.0	0.40
$32\frac{0.2}{4}$	43	63.0	1.28 (*C*)
32	43....	{ 63.0 53.0	(*C*) 1.17
$31\frac{3}{4}$	$45\frac{1}{2}$	74.0	1.46
	46	43.0	1.10

TABLE VII. *Continued.*

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$31\frac{1.4}{2}$	47	88	(P)
$31\frac{1}{2}$	47	76	1.75
Gochyaku Station.	47—48..	31 37	0.95 (C)
$31\frac{0.6}{4}$	49....	49 46	(C)
$30\frac{3.5}{4}$	49	47	1.10
$30\frac{3}{4}$	50	49	1.24
$30\frac{1.5}{2}$	51	51	1.24
$30\frac{1.5}{4}$	52	29	1.02
$30\frac{1}{4}$	53	33	0.95
$30\frac{0.5}{4}$	$52\frac{1}{2}$	47	1.06
30	52	38	0.91
$29\frac{3}{4}$	51	43	—
$29\frac{1.5}{2}$	50	27	1.02
$29\frac{1.5}{4}$	49	53	(C)
$29\frac{1}{4}$	$48\frac{1}{2}$	32	1.24
29	47....	59 (1st displ.) 120 (2nd displ.)	(P)
Sone St.	47—46	—	—
$28\frac{3}{4}$	45	133	(P)
$27\frac{3.5}{4}$	47	53	1.53
$27\frac{1}{2}$	48	65	1.39
$27\frac{0.5}{2}$	48	63	(C)

Distance from Kobe. (miles.)	Velocity. (mile/hour)	Maximum vibration.	
		$2a$ (mm)	T (sec.)
$27\frac{1.2}{4}$	48	48	(C)
$27\frac{0.5}{4}$	48....	58 38	— 0.80
$26\frac{3.7}{4}$	48	49	—
$26\frac{3}{4}$	48	31	1.02
$26\frac{1.3}{4}$	$48\frac{1}{2}$	102	1.90 (P)
Murodono Station.	$48\frac{1}{2}$	21	0.88
$26\frac{1}{4}$	$48\frac{1}{2}$	94	1.32 (P)
26	49	54	—
$25\frac{3.8}{4}$	48....	72 31	— 0.91
$25\frac{0.8}{4}$	46	72	(C)
$25\frac{0.6}{4}$	46	134	(C)
$25\frac{0.3}{4}$ (On bridge.)	43	12	0.55
	41	5	0.33
$24\frac{1.8}{4}$	40....	78 (1st displ.) 132 (2nd displ.)	(P)
Kakogawa Station.	39	125	(C)
$24\frac{1}{4}$	38....	86 104	(P)
$24\frac{0.7}{4}$	37	85	1.53
$23\frac{0.8}{4}$	37....	43 (1st displ.) 90 (2nd displ.)	(C)
$20\frac{0.5}{4}$	$34\frac{1}{2}$..	150 140	(P)
Tsuchiyama St.	32	—	—

TABLE VII. *Continued.*

Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. 2a (mm)	Maximum vibration. T (sec.)	Distance from Kobe. (miles)	Velocity. (mile/hour)	Maximum vibration. 2a (mm)	Maximum vibration. T (sec.)
$19\frac{3.5}{4}$	33....	62 (1st displ.) 132 (2nd displ.)	2.70 (*P*)	16	$35\frac{1}{2}$	31	(*P*)
				Ōkubo St.	35	8	0.66
$18\frac{1.8}{2}$	42	62	(*C*)	$15\frac{3.3}{4}$	36....	67 (1st displ.) 107 (2nd displ.)	(*P*)
$17\frac{1}{2}$	46	110	(*C*)	$15\frac{3}{4}$	36	50	(*C*)
$16\frac{0.4}{4}$	36	54	1.75 (*C*)				

An examination of Tables VI and VII shows that the lateral motion of the carriage varied very much in period, from a fraction of a second to more than of $2\frac{1}{2}$ sec. I shall provisionally divide the different vibrations into five classes as follows:—

Class I, ...Period between 0.22 and 0.59 sec.;
" II, ... " 0.61 " 0.89 " ;
" III, ... " 0.91 " 1.17 " ;
" IV, ... " 1.21 " 1.53 " ;
" V, ... " 1.64 " 2.80 " .

In Table VIII the different vibrations contained in Table VI are arranged in order of the velocities, divided into five classes as above defined; large displacements due to "curves" and "points" being excluded from Table VIII as well as Tables IX, X and XI.

TABLE VIII. RELATION BETWEEN THE LATERAL VIBRATIONS OF THE CARRIAGE, "SHAYŌ-SHA," AND THE VELOCITY. DOWN TRAIN. SANYO RAILWAY.

Velocity.	I		II		III		IV		V	
	2a	*T*	*2a*	*T*	*2a*	*T*	*2a*	*T*	*2a*	*T*
miles/hour	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
14	5	0.44								
15	10	0.58								
	4	0.55								
	3	0.44								
	4	0.44								
16	4	0.51								
17	5	0.51								
18	4.4	0.44	7.0	0.61						
	3.6	0.58								
	4	0.58								
19	3.4	0.50								
	5	0.53								
	8	0.58								
20	4	0.41								
	3.6	0.40								
	2.5	0.41								
	9	0.49								
	5.2	0.55								
	7.5	0.52								
$20\frac{1}{2}$	—	—	8.0	0.69						
21	3.2	0.44								
	4.6	0.58								
	4	0.36								
	6	0.40								
	5.2	0.44								
$21\frac{1}{2}$	4.5	0.44								
22	3.8	0.44								
	3.8	0.47								
	6	0.55								
	4	0.42								
	6	0.47								
	6	0.44								
	5	0.40								
	6	0.50								
$22\frac{1}{2}$	4.5	0.44								
	8	0.44								

TABLE VIII. *Continued.*

Velocity.	I		II		III		IV		V	
	$2a$	T	$2a$	T	$2a$	T	$2a$	T	$2a$	T
miles/hour	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
23	4.5 7 5	0.36 0.51 0.44								
24	3.9 4 3	0.47 0.40 0.36								
25	4 2	0.44 0.32	—	—	5.6 12	1.10 1.17	19	1.52		
26	—	—	—	—	11	1.06				
27	2.5 3 4	0.36 0.40 0.47	3	0.78	11 7	1.10 0.95	12	1.46		
28	3 2.5	0.40 0.22	4	0.73	8 7	1.10 0.95	10	1.42	19	1.75
$28\frac{1}{2}$	—	—	4	0.84						
29	2.8 2	0.42 0.39	4 7 4	0.84 0.73 0.69	—	—	14	1.24	14	1.64
30	1.2 2.0 5.0	0.40 0.33 0.55	9.5 7 6 18	0.73 0.73 0.62 0.88	13 31	0.95 1.10	19 18.4	1.28 1.28	13	1.90
$30\frac{1}{2}$	—	—	—	—	—	—	15	1.46		
31	2.5 2.5	0.26 0.36	8 14	0.77 0.69	10 12 7	1.02 0.91 0.95	9	1.24	48 56 44	2.4 2.2 1.9
32	—	—	12 7 6	0.77 0.73 0.73	12 5 14 8.4 21	0.91 0.88 1.10 1.02 1.10	22	1.50	14 34 42	1.64 1.90 1.75
$32\frac{1}{2}$	—	—	9	0.84						
33	3	0.40	5.6 8.4 6 5.5 7 6 9 17 8	0.73 0.88 0.73 0.73 0.73 0.80 0.80 0.80 0.73	18 22 13	1.13 1.17 0.95	25 21	1.53 1.39		

TABLE VIII. *Continued.*

Velocity.	I		II		III		IV		V	
	$2a$	T	$2a$	T	$2a$	T	$2a$	T	$2a$	T
	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
$33\frac{1}{2}$	2.5	0.36	7	0.62						
			6	0.69						
34	8	0.55	4	0.73	10	0.95	47	1.50		
			10	0.84	14	1.13				
			10	0.73	19	1.10				
			9	0.73	13	0.95				
					9.6	1.02				
					10	1.02				
$34\frac{1}{2}$	—	—	—	—	28	1.10				
35	6	0.55	9	0.80	21	1.10	16	1.28	30	2.1
	4	0.58	10	0.77	22	0.95				
			7	0.69						
			5	0.69						
$35\frac{1}{2}$	—	—	25	0.77	22	0.95				
36	5	0.51	6	0.69	12	1.10	15	1.39		
	4	0.55	12	0.80	17	0.99	18	1.50		
			8	0.88	15	1.13				
			10	0.62	12	1.10				
			11	0.73						
			11	0.73						
			11	0.84						
			7	0.80						
$36\frac{1}{2}$					22	0.99				
					14	0.91				
	—	—	—	—	21	1.06				
					30	1.06				
37	7	0.58	20	0.88	14	0.92	36	1.29		
			10	0.77	13	0.95	13	1.24		
			8	0.73	8	0.95				
			12	0.88	26	0.95				
			15	0.80	17	1.02				
			17	0.80	12	1.10				
			11	0.80						
$37\frac{1}{2}$	—	—	—	—	12	0.95	47	1.21		
38	4	0.51					24	1.28		
	7	0.51	8	0.62	28	1.10	20	1.35		
	18	0.55	7	0.69	17	1.10	16	1.46		
			24	0.84	15	0.95	27	1.24		
			8	0.62	26	0.95				
			11	0.69	13	1.06				
			9	0.66	21	0.91				
			18	0.84						
			6	0.73						
			20	0.88						
			12	0.80						
			6	0.73						
			15	0.88						

TABLE VIII. *Continued.*

Velocity.	I		II		III		IV		V	
	$2a$	T	$2a$	T	$2a$	T	$2a$	T	$2a$	T
	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
$38\frac{1}{2}$	—	—	—	—	—	—	52	1.30	37	1.86
39	6	0.58	12	0.84	15	0.93	31	1.28	28	1.83
	8	0.58	8	0.80	18	1.06	29	1.50		
			10	0.77	24	1.17	20	1.24		
			17	0.88	18	0.91				
			7	0.64	23	1.13				
			13	0.88	16	0.91				
			11	0.77	18	1.02				
			20	0.89	12	0.95				
			7	0.62	9	1.10				
			8	0.73	16	1.10				
$39\frac{1}{2}$	—	—	8	0.62	13	0.95				
			24	0.88	10	1.10				
			7	0.73	16	0.91				
			13	0.84	21	1.02				
					31	1.17				
					28	1.10				
					20	0.95				
40	3.6	0.55	11	0.66	8	0.95	—	—	48	2.20
	13	0.55	11	0.73	11	0.95			56	2.80
			11	0.69	17	0.95				
			14	0.77	7	0.95				
			13	0.80	15	0.99				
			35	0.85	22	0.99				
			20	0.77	26	0.98				
			21	0.77						
			9	0.84						
			14	0.73						
$40\frac{1}{2}$	—	—	13	0.88						
			12	0.66						
41	10	0.55	14	0.73	34	1.10	56	1.53		
	9	0.55	9	0.77	14	1.06				
			10	0.73	24	1.02				
			12	0.73	16	0.92				
			9	0.73						
			6	0.73						
			22	0.88						
$41\frac{1}{2}$	—	—	—	—	30	1.10				
42	9	0.55	11	0.69	15	0.91	13	1.24		
			12	0.88						
			9	0.77	14	1.02				
			7	0.69	28	1.02				
			13	0.77	14	0.95				
			11	0.84	25	1.06				
			15	0.88	26	1.06				

TABLE VIII. *Continued.*

Velocity.	I		II		III		IV		V	
	$2a$	T	$2a$	T	$2a$	T	$2a$	T	$2a$	T
miles/hour	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
$42\frac{1}{2}$	—	—	10	0.78						
43	9	0.51	17	0.80	32	1.17				
			23	0.84	21	0.95				
			30	0.80	19	0.91				
			26	0.73	18	1.10				
			15	0.73						
			18	0.77						
			19	0.88						
$43\frac{1}{2}$	—	—	—	—	22	0.99				
44	19	0.58	28	0.73	16	1.13				
	11	0.47	17	0.62	16	1.06				
			17	0.88	23	0.91				
$44\frac{1}{2}$	—	—	13	0.80						
			10	0.77						
			10	0.73						
45	16	0.55	22	0.88	19	1.09	37	1.46		
			16	0.73			28	1.46		
			20	0.73			34	1.46		
			28	0.80						
			14	0.84						
			22	0.73						
			40	0.80						
			19	0.69						
46	—	—	27	0.80	20	0.95	45	1.50		
			30	0.73	32	1.10				
			40	0.73						
			47	0.88						
			26	0 77						
			20	0.73						
			10	0.67						
$46\frac{1}{2}$	—	—	20	0.73	24	0.91				
			15	0.62	21	0.95				
			23	0.69						
47	13	0.58	14	0.69	26	0.91				
			21	0.84	28	0.95				
			10	0.77	25	0.98				
			13	0.73						
			21	0.89						
			21	0.88						
$47\frac{1}{2}$	—	—	18	0.84						
48	27	0.55	34	0.66	26	0.95	—	—	46	1.80
	6	0.47	39	0.69	24	0.91				
			27	0.88						
			12	0.73						
			16	0.77						
			34	0.84						
			30	0.77						

TABLE VIII. *Continued.*

Velocity.	I		II		III		IV		V	
	$2a$	T	$2a$	T	$2a$	T	$2a$	T	$2a$	T
miles/hour.	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
$48\frac{1}{2}$	—	—	32	0.69	24	0.92				
			40	0.69						
			25	0.84						
49	32	0.58	25	0.89	21	0.95				
			27	0.62						
			24	0.69						
			18	0.73						
			40	0.88						
			28	0.80						
$49\frac{1}{2}$	—	—	10	0.73						
			22	0.73						
50	26	0.59	36	0.77	34	1.17	27	1.28		
			18	0.73						
			21	0.73						
			18	0.88						
			24	0.80						
51	—	—	26	0.73						
52	—	—	18	0.77	32	1.10				
			13	0.66						

Tables IX and X give, respectively for the down train and for the up train, the average values of the $2a$ and T of the maximum lateral vibration of the carriage corresponding to the successive velocities; while Table XI give the mean results deduced from the two preceding ones. The general average values of the periods of vibrations of the five different classes, I, II, III, IV and V were respectively 0.49, 0.77, 1.05, 1.48, and 2.0 sec. The absolutely greatest vibrations in these five classes were as follows:—

Class of vibration.	$2a$ (mm)	T (sec.)	Maximum acceleration. $\left(\frac{mm}{sec.^2}\right)$
	Down Train.		
I	32	0.58	1870
II	47	0.88	1200
III	34	1.10	550
IV	56	1.53	470
V	56	2.20	230
	Up Train.		
I	12	0.55	780
II	46	0.73	1700
III	59	1.10	960
IV	85	1.53	720
V	153	1.75	990

Taking together the cases of the down and up trains as given in the above table, we find that the mutual ratios of the $2a$'s and the maximum accelerations of the most active vibrations of the five different classes were respectively as 1 : 1.4 : 1.8 : 2.7 : 4.8, and as 2.6 : 2.4 : 1.3 : 1 : 1.4.

TABLE IX. RELATION BETWEEN THE LATERAL VIBRATION OF THE CARRIAGE, "*SHAYŌ-SHA*," AND THE VELOCITY OF THE TRAIN. (MEAN RESULTS.)

DOWN TRAIN.

Velocity.	I		II		III		IV		V	
	2a	*T*	*2a*	*T*	*2a*	*T*	*2a*	*T*	*2a*	*T*
miles/hour	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
14	5.0	0.44								
15	5.3	0.50								
16	4.0	0.51								
17	5.0	0.51								
18	4.0	0.53	7.0	0.61						
19	5.5	0.54								
20	5.3	0.46	8.0	0.69						
21	4.6	0.44								
22	5.2	0.46								
23	5.5	0.44								
24	3.6	0.41								
25	3.0	0.38	—	—	8.8	1.14	19.0	1.52	—	—
26	—	—	—	—	11.0	1.06	—	—	—	—
27	3.2	0.41	3.0	0.78	9.0	1.03	12.0	1.46	—	—
28	2.8	0.31	4.0	0.73	7.5	1.03	10.0	1.42	19.0	1.75
29	2.4	0.41	4.8	0.78	—	—	14.0	1.24	14.0	1.65
30	2.7	0.43	10.1	0.74	22.0	1.03	18.7	1.28	13.0	1.90
31	2.5	0.31	11.0	0.73	9.7	0.96	12.0	1.35	49.3	2.20
32	—	—	8.3	0.74	12.1	1.00	22.0	1.50	30.0	1.76
33	3.0	0.40	8.2	0.79	17.8	1.08	23.0	1.46	—	—
34	5.3	0.46	7.7	0.72	12.6	1.03	47.0	1.50	—	—
35	5.0	0.57	7.8	0.74	23.7	1.05	16.0	1.28	30.0	2.10
36	4.5	0.53	11.2	0.76	15.6	1.05	16.5	1.45	—	—
37	7.0	0.58	—	0.81	17.7	0.99	24.5	1.27	—	—
38	9.7	0.52	12.0	0.75	18.9	1.00	26.8	1.31	—	—
39	7.0	0.58	10.3	0.78	16.9	1.03	33.0	1.33	32.5	1.85
40	8.3	0.55	15.1	0.76	17.5	1.00	—	—	52.0	2.50
41	9.5	0.55	11.9	0.76	22.0	1.03	56.0	1.53	—	—
42	9.0	0.55	11.1	0.79	21.7	1.02	13.0	1.24	—	—
43	9.0	0.51	19.8	0.79	22.5	1.03	—	—	—	—
44	15.0	0.53	20.7	0.74	19.3	1.02	—	—	—	—
45	16.0	0.55	19.5	0.77	19.0	1.09	33.0	1.46	—	—
46	—	—	28.9	0.76	26.0	1.03	45.0	1.50	—	—
47	13.0	0.58	17.6	0.76	24.8	0.94	—	—	—	—
48	16.5	0.51	26.3	0.77	25.0	0.94	—	—	46.0	1.80
49	32.0	0.58	28.8	0.76	22.5	0.94	—	—	—	—
50	26.0	0.59	21.3	0.77	34.0	1.17	27.0	1.28	—	—
51	—	—	26.0	0.73	—	—	—	—	—	—
52	—	—	15.5	0.72	32.0	1.10	—	—	—	—

TABLE X. RELATION BETWEEN THE LATERAL VIBRATION OF THE CARRIAGE, "*SHAYŌ-SHA*," AND THE VELOCITY OF THE TRAIN. (MEAN RESULTS.)

UP TRAIN.

Velocity.	I		II		III		IV		V	
	2a	T	2a	T	2a	T	2a	T	2a	T
miles/hour	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
15	4.7	0.53	4.8	0.69						
16	—	—								
17	—	—								
18	7.3	0.55	5.9	0.62						
19	5.6	0.50	6.0	0.73						
20	5.2	0.51	—	—						
21	4.4	0.47	—	—						
22	4.8	0.43	—	—						
23	4.8	0.43	—	—						
24	5.0	0.44	—	—	7.0	0.95				
25	5.5	0.39	—	—	10.5	1.06	—	—	—	—
26	4.5	0.40	—	—	—	—	—	—	21.0	1.68
27	3.5	0.46	7.7	0.69	10.3	1.04	16.0	1.38	—	—
28	3.7	0.35	—	—	—	—	26.0	1.38	—	—
29	—	—	8.5	0.81	—	—	—	—	58.0	2.00
30	2.3	0.31	8.0	0.79	19.3	1.05	—	—	—	—
31	—	—	12.5	0.81	18.0	1.17	30.0	1.53	29.5	1.71
32	4.5	0.55	—	—	12.0	0.91	24.0	1.43	34.0	1.90
33	—	—	7.2	0.73	17.0	1.02	21.5	1.33	18.0	1.64
34	—	—	11.0	0.81	25.3	1.13	19.5	1.39	64.0	2.20
35	—	—	12.7	0.79	14.6	1.01	—	—	48.0	1.74
36	7.0	0.55	19.5	0.86	25.5	1.13	—	—	54.8	1.80
37	6.0	0.55	10.0	0.73	19.7	1.01	85.0	1.53	—	—
38	—	—	16.7	0.75	15.8	0.98	36.5	1.26	—	—
39	—	—	19.6	0.84	24.0	1.09	51.0	1.35	26.5	1.87
40	—	—	28.5	0.81	27.4	1.08	—	—	153.0	1.75
41	5.0	0.33	25.0	0.73	24.3	0.99	—	—	102.0	2.80
42	—	—	25.0	0.82	22.3	1.03	—	—	148.0	2.60
43	9.0	0.55	16.8	0.79	29.5	1.09	63.0	1.28	94.5	2.40
44	12.0	0.58	23.6	0.75	28.8	1.06	—	—	58.0	1.57
45	—	—	26.0	0.74	20.5	1.01	—	—	152.0	2.20
46	—	—	29.3	0.77	37.0	1.10	77.5	1.57	—	—
47	—	—	30.8	0.72	59.0	1.10	53.0	1.53	76.0	1.75
48	11.0	0.55	27.7	0.80	31.0	1.02	42.3	1.31	126.0	2.10
49	—	—	33.5	0.81	36.5	1.03	32.0	1.24	—	—
50	—	—	15.0	0.73	33.7	0.96	49.0	1.24	—	—
51	—	—	—	—	—	—	51.0	1.24	—	—
52	—	—	23.0	0.69	33.5	0.97	—	—	—	—
53	—	—	24.0	0.73	40.0	1.01	—	—	—	—

TABLE XI. RELATION BETWEEN THE LATERAL VIBRATION OF THE CARRIAGE, "*SHAYŌ-SHA*," AND THE VELOCITY OF THE TRAIN. (MEAN RESULTS.)

UP AND DOWN TRAINS.

Velocity.	I		II		III		IV		V	
	$2a$	T	$2a$	T	$2a$	T	$2a$	T	$2a$	T
miles/hour.	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.
14	5.0	0.44								
15	5.0	0.52	4.8	0.69						
16	4.0	0.51								
17	5.0	0.51								
18	5.7	0.54	6.5	0.62						
19	5.6	0.52	6.0	0.73						
20	5.3	0.49	8.0	0.69						
21	4.5	0.46								
22	5.0	0.45								
23	5.2	0.44								
24	4.3	0.43			7.0	0.95				
25	4.3	0.39	—	—	9.7	1.10	19.0	1.52	—	—
26	4.5	0.40	—	—	11.0	1.06	—	—	21.0	1.68
27	3.4	0.44	5.4	0.74	9.7	1.04	14.0	1.42	—	—
28	3.3	0.33	4.0	0.73	7.5	1.03	18.0	1.40	19.0	1.75
29	2.4	0.41	6.7	0.80	—	—	14.0	1.24	36.0	1.83
30	2.5	0.37	9.1	0.77	20.7	1.04	18.7	1.28	13.0	1.92
31	2.5	0.31	11.8	0.77	13.9	1.07	21.0	1.44	39.4	1.96
32	4.5	0.55	8.3	0.74	12.1	0.96	23.0	1.47	32.0	1.83
33	3.0	0.40	7.7	0.76	17.4	1.05	22.3	1.40	18.0	1.64
34	5.3	0.46	9.4	0.77	19.0	1.08	33.3	1.43	64.0	2.20
35	5.0	0.57	10.3	0.77	19.2	1.03	16.0	1.28	39.0	1.92
36	5.8	0.54	15.4	0.81	20.6	1.09	16.5	1.45	54.8	1.80
37	6.5	0.57	12.7	0.77	18.7	1.00	54.8	1.40	—	—
38	9.7	0.52	14.4	0.75	17.4	0.99	31.7	1.29	—	—
39	7.0	0.58	15.0	0.81	20.5	1.06	42.0	1.34	29.5	1.86
40	8.3	0.55	21.8	0.79	22.5	1.04	—	—	102.5	2.13
41	7.3	0.44	18.5	0.75	23.2	1.01	56.0	1.53	102.0	2.80
42	9.0	0.55	18.1	0.81	22.0	1.03	13.0	1.24	148.0	2.60
43	9.0	0.53	18.3	0.79	26.0	1.06	—	—	94.5	2.40
44	13.5	0.56	22.2	0.75	24.1	1.04	63.0	1.28	58.0	1.57
45	16.0	0.55	22.8	0.76	19.8	1.05	33.0	1.46	152.0	2.20
46	—	—	29.1	0.77	31.5	1.07	61.3	1.54	—	—
47	13.0	0.58	24.2	0.74	41.9	1.02	53.0	1.53	76.0	1.75
48	13.8	0.53	27.0	0.79	28.0	0.98	42.3	1.31	86.0	1.95
49	32.0	0.58	31.2	0.79	29.5	0.99	—	—	—	—
50	26.0	0.59	18.2	0.75	33.9	1.07	32.0	1.24	—	—
51	—	—	26.0	0.73	—	—	38.0	1.26	—	—
52	—	—	19.3	0.71	32.8	1.04	51.0	1.24	—	—
53	—	—	24.0	0.73	40.0	1.01	—	—	—	—

From Tables IX to XI, it will be seen that the vibration of the I class occurred throughout the whole range of the velocity, while the vibrations of the other classes occurred, with a few exceptions, only for values of the velocity higher than some 25 miles per hour. Figs. 2 and 3 illustrate respectively the relation between the velocity of the train and the maximum $2a$ of the lateral vibration of the I class and of the II and III classes combined.

Fig. 2 shows that the vibration of the I class remained practically constant for the values of the velocity between 14 and 35 miles per hour, the max. $2a$ during this interval being 5.7 mm. With velocities higher than 35 miles per hour, the increase of the $2a$ became quick, reaching a mean value of about 30 mm at the velocity of 50 miles per hour.

Fig. 3 shows that the vibrations of the II and III classes did not much vary between the velocities of 15 and some 29 miles per hour, the greatest value of the $2a$ during this interval being 11 mm. Thereafter the $2a$ increased rapidly and nearly in proportion to the velocity, attaining the mean value of about 35 mm at a velocity of about 53 miles per hour.

The vibrations of the IV and V classes were most active for values of the velocity between some 34 and 52 (upper limit in the experiment) miles per hour.

Looking together at the vibrations of the different classes the lateral motion of the carriage became markedly strong with a velocity of about 30 miles per hour.

In the 2nd experiment on the Tokaido line with the experimental carriage "kyokuyo-sha" of the Government Railways, the lateral vibration assumed a marked increase at a lower value of the velocity, namely, that of about 23 miles per hour. (See the *Publications*, No. 15.) In the following table the mean values of vibration of the carriage above mentioned are compared with those of the III class vibration of the "shayo-sha," deduced from Table XI; the periods of vibration of this latter class being nearly equal to those of the "kyokuyo-sha" as given in my former analysis.

TABLE XII. COMPARISON OF LATERAL VIBRATIONS OF THE TWO CARRIAGES "KYOKUYŌ-SHA" AND "SHAYŌ-SHA."

Velocity.	Kyokuyō-sha. (TokaidōRailway.)	Shayō-sha. (Sanyō-Railway.)	Ratio : [Kyokuyō-sha.] / [Shayō-sha.]
miles/hour	mm	mm	mm
7	6.8	—	—
12	8.8	—	—
17	11.5	—	—
22	12.4	—	—
27	17.6	9.5	1.9
32	25.0	16.6	1.5
37	34.2	19.3	1.8
42	26.2	23.6	1.1
47	—	30.1	—
52	—	35.6	—
MEAN			**1.6**

From the above table, it will be seen that the vibration of the carriage "kyokuyō-sha" was greater than that of the "shayō-sha" in the mean ratio of 1.6 : 1, due probably to the fact that the wheels of the latter carriage had cylindrical tires, while such was not the case with the former; the position of the experimental carriage in the train being similer in the two cases, namely, coupled directly to the engine.

LATERAL VIBRATION CAUSED BY "CURVES."

7. The carriages, when running with a high velocity, always experienced violent lateral displacements at the beginning and end of a *curve*, which consists of a circular arc joined to tangents at both extremities. (See also p.p. 32–34 of the *Publications*, No. 15.) By comparing Tables VI and VII with Table XIII, which gives a list of *curves* on the Sanyō Railway, between Kobe and Okayama, we may find out the effects due to the successive *curves*. Tables XIV and XV give, respectively for the down train and for the up train, examples of large lateral vibrations produced by *curves*, together with the velocity of the train and the radii of the latter; the displacement being denoted by a or $2a$ according as it corresponds to a single amplitude or double amplitude. (Illustrative diagrams are given in Pl. VII.)

TABLE XIII. LIST OF THE CURVES ON THE SANYŌ RAILWAY, BETWEEN KOBE AND OKAYAMA.

Radius of *curve*.	Position of *curve*. (Distance from Kobe).		Radius of *curve*.	Position of *curve*. (Distance from Kobe.)	
	Beginning.	End.		Beginning.	End.
chains	miles	miles	chains.	miles	miles
9	0.10—	0.16	20	7.06—	7.08
15	0.26—	0.32	18	7.08—	7.13
20	0.78—	0.87	20	7.14—	7.17
20	0.88 —	1.00	30	7.31—	7.36
60	1.50 —	1.53	30	7.37—	7.45
80	2.60 —	2.65	30	7.48—	7.52
62	4.00 —	4.30	40	7.58—	7.62
40	4.70 —	4.74	40	7.76—	7.82
40	4.90 —	5.12	40	8.00—	8.10
30	5.24—	5.39	60	8.40 —	8.46
40	5.53—	5.62	40	8.62—	8.73
40	6.06—	6.11	40	8.78—	9.06
40	6.34—	6.40	40	9.53—	9.61
30	6 90—	6.97	42	9.72—	9.94
23	6.97—	7.04	20	10.07—	10.14

TABLE XIII. *Continued.*

Radius of *curve*.	Position of *curve*. (Distance from Kobe). Beginning.	End.
chains	miles	miles
30	10.25	10.31
70	10.37	10.55
40	10.64	10.70
30	10.76	10.82
40	11.11	11.21
40	12.11	12.17
30	12.51	12.67
80	13.32	13.37
80	14.22	14.40
40	14.60	14.67
40	16.16	16.35
80	17.17	17.24
40	17.52	17.85
40	18.66	18.78
80	20.64	20.82
60	22.25	22.37
60	23.12	23.20
30	24.10	24.21
40	25.20	25.43
80	27.30	27.68
80	28.58	28.65
30	28.73	29.00
60	29.38	29.51
80	31.50	31.62
40	32.05	32.23
40	34.23	34.49
80	36.26	36.40
40	37.15	37.36
40	38.72	38.80
40	39.22	39.27
40	39.72	39.82
80	40.85	40.93
40	42.30	42.50
30	43.18	43.43
40	44.30	44.39
40	45.30	45.43
40	46.04	46.16
60	46.54	46.81
30	47.19	47.45
40	47.66	47.98
40	50.22	50.31
40	50.35	50.49
20	50.56	50.71

Radius of *curve*.	Position of *curve*. (Distance from Kobe). Beginning.	End.
chains	miles	miles
30	51.54	51.82
20	52.12	52.37
60	52.76	52.82
40	53.06	53.19
40	54.09	54.68
30	55.25	55.50
40	55.63	56.04
30	56.40	56.83
22	57.34	57.82
40	57.88	58.08
60	58.40	58.49
20	58.73	58.94
80	59.04	59.17
30	59.17	59.23
16	59.53	59.80
40	59.91	60.15
25	60.72	60.87
35	60.89	61.21
40	61.50	61.68
25	62.49	62.57
30	62.60	62.71
38	62.79	63.03
60	63.15	63.46
60	63.58	63.65
40	63.66	63.70
22	63.85	64.27
30	64.30	64.40
30	64.49	64.57
40	64.70	64.77
20	64.99	65.08
40	65.18	65.25
30	65.72	66.06
25	66.06	66.28
40	66.61	66.70
30	66.91	67.00
60	67.50	67.65
80	68.22	68.33
40	68.89	69.12
40	69.85	70.11
80	70.38	70.47
60	71.40	71.65
20	71.98	72.08

TABLE XIII. *Continued.*

Radius of *curve*.	Position of *curve*. (distance from Kobe). Beginning. End.	Radius of *curve*.	Position of *curve*. (distance from Kobe). Beginning. End.
chains	miles miles	chains	miles miles
30	72.09—72.20	30	79.85—79.97
40	72.49—72.61	30	80.06—80.32
30	72.68—72.81	40	81.30—81.54
30	72.92—73.06	40	81.69—82.00
30	73.16—73.30	40	82.15—82.28
30	73.42—73.54	40	84.07—84.29
20	73.72—73.98	40	86.85—87.01
30	74.37—74.60	80	87.23—87.34
40	74.97—75.18	40	87.52—87.69
30	75.69—75.74	40	87.97—88.55
22	75.74—76.06	20	89.23—89.42
40	76.26—76.49		
120	76.77—76.98		
80	78.32—78.49		
40	79.15—79.38		

TABLE XIV. LARGE LATERAL VIBRATIONS PRODUCED BY *CURVES*.*

DOWN TRAIN.

Distance from Kobe.	Velocity.	Radius of *curve*.	a	$2a$	T
miles.	miles/hour.	chains.	mm	mm	sec.
$10\frac{1.5}{2}$	$39\frac{1}{2}$	40	—	112	—
$25\frac{1}{4}$	41	40	—	109	1.80

* [S] Denotes an S-*curve*.

TABLE XIV. *Continued.*

Distance from Kobe.	Velocity.	Radius of *curve*.	a	$2a$	T
miles.	miles/hour.	chains.	mm	mm	sec.
$27\frac{1}{2}$	48	80	—	110	—
$37\frac{1}{4}$	45	40	80 ; 86 ;	140 133	1.80 —
$38\frac{3.5}{4}$	49	40		66 68	0.95
$39\frac{1}{4}$	46	40		100	—
$42\frac{1}{2}$	37	40		106	—
46	41	40		102 102	2.70
$50\frac{1.3}{2}$	36	20		118 64	— [*S*]
$52\frac{1.5}{4}$	38	20		117 125	2.40 2.60
$53\frac{0.4}{4}-\frac{1.5}{2}$	42	40	59 ; — ;	118 94	[*S*]
$64\frac{1}{4}$	37	22		112 95	2.30 2.20
$64\frac{1}{2}$	36	30		109 102	— —
65	$42\frac{1}{2}$	20		146	—
$65\frac{1}{4}$	44	40		90	—
66	$49\frac{1}{2}$	30—25		164	[*S*]
$66\frac{1}{4}$	50	25		144	—

TABLE XIV. *Continued.*

Distance from Kobe.	Velocity.	Radius of *curve*.	a	$2a$	T
miles.	miles/hour.	chains.	mm	mm	sec.
$66\frac{3.5}{4}$	$51\frac{1}{2}$	30		122	[*S*]
6	52	30		150	
$66\frac{1}{2}$	51	40		107	—
$66\frac{3}{4}$	$51\frac{1}{2}$	40		121	—
70	40	40		52	—
72	35	20—30		117	—
73	43	30		118	2.10
$73\frac{1}{4}$	44	30		60	—
$73\frac{3}{4}$	46	20		136	[*S*]
74	47	20		138	
$74\frac{1}{2}$	48	30		93	—
$75\frac{3}{4}$	48	30 22	79 ;	— 156	[*S*]
$81\frac{1}{2}$	46	40		112	—
87	37	40		72	—
$87\frac{1}{2}$	$39\frac{1}{2}$	40		70	—
88	$37\frac{1}{2}$	40	86 ;	122	—

TABLE XV. LARGE LATERAL VIBRATIONS PRODUCED BY *CURVES.*

UP TRAIN.

Distance from Kobe.	Velocity.	Radius of *curve.*	a	$2a$	T
miles.	miles/hour.	chains.	mm	mm	sec.
$17\frac{1}{2}$	46	40		110	—
24	39	30		125	—
$25\frac{0.6}{4}$	46	40		134	—
$37\frac{0.5}{4}$	48	40		130	1.90
$37\frac{1.2}{4}$	45	40		152	2.20
$52\frac{1.5}{4}$	40	20		152	1.75
$56\frac{1.5}{4}$	49	30		120	—
$57\frac{1.4}{4}$	50	22		132	—
$57\frac{3.5}{4}$	50	22		128	—
$58\frac{1.6}{4}$	53	40		108	—
$58\frac{3}{4}$	51	20		144	—
59	50	20		115	1.53
$59\frac{1}{4}$	$48\frac{1}{2}$	30		103	—
$59\frac{1}{2}$	48	16		122	2.30
$59\frac{3.4}{4}$	47	16		116	—
72	39	20		100	—
$72\frac{0.3}{4}$	41	30		102	2.80 [S]
$72\frac{1}{2}$	44	40		113	—
$73\frac{1}{4}$	$43\frac{1}{2}$	30		105	—
74	42	20		150	2.20

TABLE XV. *Continued.*

Distance from Kobe.	Velocity.	Radius of *curve.*	a	$2a$	T
miles.	miles/hour.	chains.	mm	mm	sec.
$75\frac{3}{4}$	34	22—30		118	— [S]
$80\frac{1.5}{4}$	43	30		102	2.90
$16\frac{0.4}{4}$	36	40		54	1.75
$32\frac{0.2}{4}$	43	40		63	1.28
$75\frac{1}{4}$	39	40		27	1.64
$84\frac{1}{4}$	32	40		23	1.46

Some of the largest vibrations contained in the two preceding tables, for which the period is given, are as follows:—

a (mm)	$2a$ (mm)	T (sec.)	Maximum acceleration $\left(\frac{\text{mm}}{\text{sec.}^2}\right)$
—	109	1.80	670
80	140	1.80	980
—	68	0.95	1500
—	118	2.10	530
—	130	1.90	710
—	152	1.80	980
—	115	1.53	970
—	152	2.20	620

Thus the greatest $2a$ corresponding to the period of 1.8 sec. was 152 mm, with the maximum acceleration of about 1000 mm per sec. per sec.; while the greatest $2a$ corresponding to a period of about 1 sec. was 68 mm, with the maximum acceleration of 1500 mm. These shakings of the carriage "shayo-sha" produced by *curves* are somewhat maller than some of the strongest shakings of the carriage "kyokuyo-sha" on the Tokaido line. (See the *Publications*, No. 15, pp. 61–66.).

8. The following table gives a comparison of the lateral vibrations of the carriage "shayo-sha" at the beginning and end of each of the different *curves*.

TABLE XVI. COMPARISON OF THE LATERAL VIBRATIONS OF THE CARRIAGE "*SHAYO-SHA*" PRODUCED WHEN ENTERING, AND WHEN LEAVING, THE *CURVES*.

DOWN TRAIN.

Velocity.	Radius of *curve*.	$2a$ produced when the carriage	
		entered a *curve*.	left a *curve*.
miles/hour.	chains.	mm	mm
35—36	60	25	21
36—37	40	88	58
41—40	40	34	31
43½	40	63	63
45	40	140	133
49	40	43	68
38—37	40	49	106
51—51½	40	107	121
51½—52	30	122	150
29—37	22	165	112
48—42	22	156	120
46—47	20	136	138
MEAN.	—	**94**mm	**94**mm

UP TRAIN.

Velocity.	Radius of *curve*.	entered a *curve*.	left a *curve*.
48—48	80	63	48
43—43	40	63	63
33—40	40	52	91
48—45	40	152	130
32—34	40	85	0
43—35	40	72	94
32—29	40	52	18
45—44	40	94	77
42—40	40	80	48
39—39	40	30	70
32—34	40	23	24
49—50	30	80	120
25½—26½	25	0	25
50—50	22	128	132
51—50	20	115	144
48—47	16	116	122
MEAN.	—	**75**mm	**75**mm

From the above table it seems that a carriage experiences an equal amount of shock when entering a curve as when leaving it.

9. In Tables XVII and XVIII, which relate respectively to the down and up trains, the lateral shakings of the carriage produced by *curves* are arranged according to the radii of the latter, the quantity k given in the 4th column being defined as follows :—

$$k=\frac{\text{Velocity (in miles per hour)}}{\text{Radius of the curve (in chains)}}.$$

The numerals in brackets, (1) and (2), suffixed to $2a$'s signify that the latter related respectively to the beginning and end of a curve, taken in the direction from Kobe to Okayama.

TABLE XVII. LATERAL VIBRATIONS PRODUCED BY CURVES.

DOWN TRAIN.

Velocity.	Radius of *curve.*	$2a$	k	Velocity.	Radius of *curve.*	$2a$	k
miles/hour.	chains.	mm		miles/hour.	chains.	mm	
35	80	35	0.44	$48\frac{1}{2}$	60	36	0.81
40	80	32	0.50				
39	80	29	0.49	38	60	64	0.63
				34	60	28	0.57
48	80	110	0.60	27	40	69	0.68
45	80	20	0.56	29	40	29	0.73
35	80	34	0.44	38	40	26	0.95
				40	40	42	1.00
36	80	11	0.45	40	40	44	1.00
40	80	26	0.50	42	40	50	1.05
				39	40	26	0.98
36	60 (1)	25	0.60	$39\frac{1}{2}$	40	112	0.99
35	60 (2)	21	0.58				
47	60	34	0.78	42	40	52	1.05

TABLE XVII. *Continued.*

Velocity.	Radius of *curve.*	$2a$	k
miles/hour.	chains.	mm	
36	40 (1)	88	0.90
37	40 (2)	58	0.93
41	40 (1)	34	1.03
40	40 (2)	31	1.00
$43\frac{1}{2}$	40 (1)	63	1.09
$43\frac{1}{2}$	40 (2)	63	1.09
41	40	109	1.03
40	40	80	1.00
45	40 (1)	140	1.13
45	40 (2)	133	1.13
49	40 (1)	43	1.23
49	40 (2)	68	1.23
40	40	100	1.15
38	40 (1)	49	0.95
37	40 (2)	106	0.93
35	40	58	0.88
41	40	102	1.03
42	40	118	1.05
22	40	6	0.55
44	40	90	1.10
51	40 (1)	107	1.28
$51\frac{1}{2}$	40 (2)	121	1.29
40	40	52	1.00
46	40	112	1.15
38	40	65	0.95

Velocity.	Radius of *curve.*	$2a$	k
miles/hour.	chains.	mm	
37	40	72	0.93
$39\frac{1}{2}$	40	70	0.99
$37\frac{1}{2}$	40	122	0.94
33	30	36	1.10
40	30—23	145	1.74
39	30	35	1.30
31	30	48	1.03
$47\frac{1}{2}$	30	96	1.58
$49\frac{1}{2}$	30—25	164	1.62
$51\frac{1}{2}$	30 (1)	122	1.72
52	30 (2)	150	1.73
44	30	60	1.47
48	30	93	1.60
48	30	79	1.60
50	25	144	2.00
36	22	109	1.64
48	22 (1)	156	2.19
42	22 (2)	120	1.91
29	22 (1)	165	1.32
37	22 (2)	112	1.68
36	20	118	1.80
38	20	125	1.90
$42\frac{1}{2}$	20	146	2.13
35	20	117	1.75
46	20	136	2.30
47	20	138	2.35

TABLE XVIII. LATERAL VIBRATIONS OF THE CARRIAGE PRODUCED BY *CURVES*. SANYO RAILWAY.

UP TRAIN.

Velocity.	Radius of *curve.*	$2a$	k	Velocity.	Radius of *curve.*	$2a$	k
miles/hour.	chains.	mm		miles/hour.	chains.	mm	
48	80 (2)	48	0.60	$34\frac{1}{2}$	40	0	0.86
48	80 (1)	63	0.60	$34\frac{1}{2}$	40	59	0.86
48	80	56	0.60	44	40	0	1.10
35	80	0	0.44	43	40 (2)	94	1.08
29	80	0	0.36	35	40 (1)	72	0.88
37	60	90	0.62	53	40	108	1.33
49	60	53	0.82	$45\frac{1}{2}$	40	73	1.14
34	60	79	0.57	$23\frac{1}{2}$	40	4	0.59
36	40	54	0.90	32	40 (2)	18	0.80
46	40	110	1.15	29	40 (1)	52	0.73
42	40	62	1.05	27	40	40	0.68
46	40	134	1.15	44	40	113	1.10
46	40	72	1.15	39	40	27	0.98
43	40 (2)	63	1.08	49	40 (2)	77	1.13
43	40 (1)	63	1.08	44	40 (1)	94	1.10
33	40 (2)	91	0.83	42	40 (2)	48	1.05
40	40 (1)	52	1.00	40	40 (1)	80	0.50
48	40 (2)	130	1.20	39	40 (2)	70	0.56
45	40 (1)	152	1.13	39	40 (1)	30	0.98
45	40	60	1.13	34	40 (2)	24	1.42
34	40 (2)	0	0.85	32	40 (1)	23	0.80
32	40 (1)	85	0.80				

TABLE XVIII. *Continued.*

Velocity.	Radius of *curve.*	$2a$	k	Velocity.	Radius of *curve.*	$2a$	k
miles/hour.	chains.	mm		miles/hour.	chains.	mm	
32	40	32	1.00	40	25	74	1.60
25	40	54	0.63				
$23\frac{1}{2}$	40	0	0.59				
$36\frac{1}{2}$	35	56	1.04	$25\frac{1}{2}$	{25 (2)	{72	{1.02
39	30	125	1.30	$26\frac{1}{2}$	{25 (1)	{0	{1.06
43	30	88	1.43				
				50	{22 (2)	{132	{2.27
				50	{22 (1)	{128	{2.27
49	{30 (2)	{120	{1.63				
50	{30 (1)	{80	{1.67				
				22	22	0	1.00
$48\frac{1}{2}$	30	103	1.62				
$43\frac{1}{2}$	30	105	1.45	38	{20 (2)	{—	{—
43	30	78	1.43	40	{20 (1)	{152	{2.00
40	30	70	1.33	51	{20 (2)	{144	{2.55
43	30	102	1.43	50	{20 (1)	{115	{2.50
39	{20	{100	{1.95 [S]	23	20	0	1.15
41	{30	{102	{1.37 [S]	42	20	150	2.10
34	{22	118	1.54 [S]	48	{16 (2)	{122	{3.00
34	{30			47	{16 (1)	{116	{2.94

The following are some of remarks on Tables XVI and XVII.

Curves of 80 chains radius. The lateral vibration was not particularly large, the greatest $2a$ for the velocities between 29 and 45 miles per hour being 35 mm. In one of the four cases, in which the velocity was 48 miles per hour, the maximum $2a$ was 110 mm, while in the remaining three it varied between 48 and 63 mm.

Curves of 60 chains radius. The $2a$ varied from 21 to 90 mm, for velocities between 34 and 49 miles per hour.

Curves of 40 chains radius. The curve effect was, for velocities under $23\frac{1}{2}$ miles per hour, practically *nil*. For velocities between 24 and 30 miles per hour, the $2a$ varied from 29 to 69 mm. Large $2a$'s over 100 mm occurred first with the velocity of 37 miles per hour. For velocities between 37 and 53 miles per hour, the greatest $2a$ was 152 mm.

Curves of radii from 30 to 25 chains. Large vibrations of 100 mm or more appeared already with the velocity of 30 miles per hour; the greatest $2a$ being 164 mm, which occurred with a velocity of $49\frac{1}{2}$ miles per hour.

Curves of radii of 22 to 20 chains. In two cases, in which the velocities was respectively 22 and 23 miles per hour, there was no sudden shock produced by the curves. In the remaining 18 cases, in which the velocity varied between 29 and 51 miles, none of the $2a$'s was smaller than 109 mm; the greatest $2a$ being 165 mm.

Curves of 16 chains radius. In the two cases of 16 chains curves contained in Table XVIII, the velocities were respectively 47 and 48 miles per hour; the corresponding $2a$'s being 116 and 122 mm.

From the above statements, it will be seen that the curves of 60 to 80 chains radii did not produce lateral vibrations of the carriage greater than 100 mm, throughout the whole range of the velocity, except in a single instance. On the other hand, the curves of 16 to 22 chains radii produced, for velocities higher than 29 miles per hour, always large vibrations exceeding 100 mm.

10. ***Relation between the velocity, the radius of the curve, and the lateral vibration.*** In the following two tables the lateral vibrations are arranged according to the increasing value of k, or the ratio of the velocity to the radius.

TABLE XIX. LATERAL VIBRATION OF THE CARRIAGE CAUSED BY CURVES, ARRANGED ACCORDING TO k.

DOWN TRAIN.

k	$2a$	k	$2a$	k	$2a$
	mm		mm		mm
0.44	35	0.98	26	1.28	107
0.44	34	0.99	112	1.29	121
0.45	11	0.99	70	1.32	165
0.49	29	1.00	80	1.47	60
0.50	32	1.00	42		
0.50	26	1.00	52		
				1.58	96
0.55	6	1.00	44	1.60	63
0.56	20	1.00	31	1.60	79
0.58	21	1.03	34		
				1.62	164
0.57	28	1.03	109	1.64	109
0.60	25	1.03	48	1.68	112
0.60	110	1.03	102		
0.63	64	1.05	118	1.72	122
0.68	69	1.05	50	1.73	150
		1.05	52	71.4	145
0.73	20	1.09	63		
0.78	34	1.10	36	1.75	117
0.81	36	1.10	90	1.80	118
0.88	58	1.13	140		
0.90	88	1.13	133	1.90	125
0.93	58	1.15	100	1.91	120
				2.00	144
0.93	106	1.15	112		
0.93	72				
0.94	122			2.13	146
				2.19	156
0.95	65	1.23	43	2.30	136
0.95	26	1.23	68		
0.95	49	1.30	35	2.35	138

TABLE XX. LATERAL VIBRATION OF THE CARRIAGE CAUSED BY CURVES, ARRANGED ACCORDING TO *k*.

UP TRAIN.

k	2*a*	*k*	2*a*	*k*	2*a*
	mm		mm		mm
0.36	0	0.98	27	1.30	125
0.44	0	0.98	30	1.33	108
0.50	80	1.00	52	1.33	70
0.56	70	1.00	0		
				1.37	102
0.57	79	1.00	32		
				1.42	24
0.59	4	1.02	72		
				1.43	102
0.59	0	1.04	56		
0.60	48	1.05	62	1.43	78
0.60	63	1.05	48	1.43	88
				1.45	105
0.60	56	1.06	0		
0.62	90	1.08	63		
				1.54	118
0.63	54	1.08	63		
				1.60	74
				1.62	103
0.68	40	1.08	94		
		1.10	94		
		1.10	0	1.63	120
				1.67	80
		1.10	113		
0.73	52				
0.80	23				
0.80	85			1.95	100
		1.13	152	2.00	152
0.80	18	1.13	60	2.10	150
0.82	53	1.13	77		
0.83	91				
				2.27	132
		1.15	110		
				2.27	128
0.85	0	1.15	134		
				2.50	115
0.86	0	1.15	72		
0.86	59				
		1.15	0	2.55	144
0.88	72	1.14	73	2.94	116
0.90	54	1.20	130	3.00	122

The mean values of the k and $2a$ of the different groups contained in the two preceding tables are as follows.

Down Train.		Up Train.	
k	$2a$	k	$2a$
0.54	mm 36	0.56	mm 45
0.91	63	0.83	46
1.06	76	1.05	50
1.30	86	1.15	90
1.68	119	1.48	93
2.11	138	2.40	129
mean . . **1.27**	mm **86.3**	**12.5**	mm **75.6**
$2a=68\,k$		$2a=60\,k$	

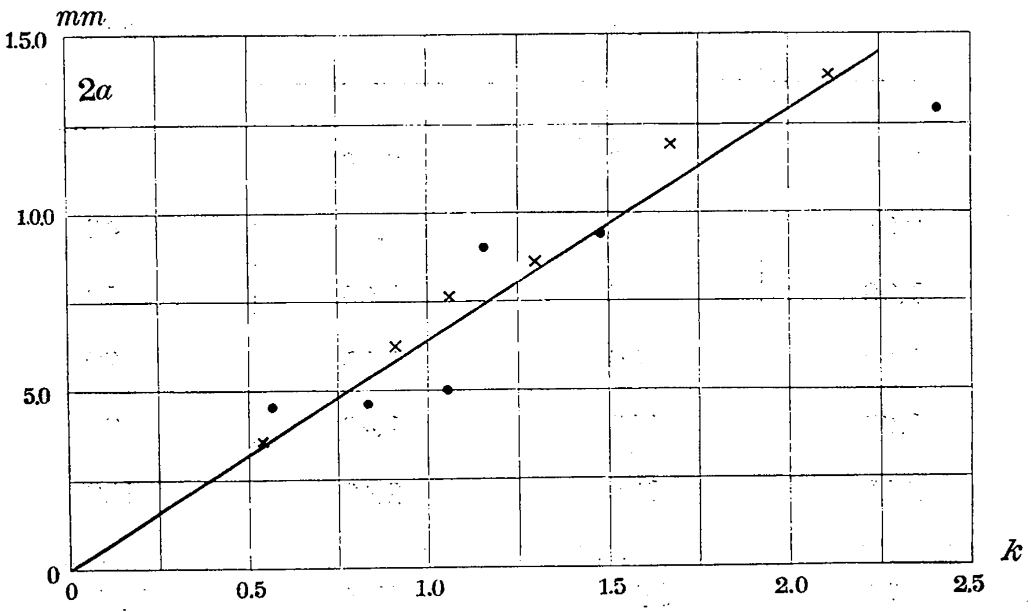
The results contained in the above table are illustrated in the accompanying figure. Remembering that the $2a$'s corresponding to the high values of k, such as 2.11 or 2.40, would be too small, owing to the fact that the horizontal vibration measurer was not able to record accurately very large vibrations, the relation between k and $2a$ is in each to be regarded as a straight line. The average relation is expressed by the equation $2a=68\,k$ in the case of the down train, and by the equation $2a=60\,k$ in the case of the up train. Taking the mean from these two equations, we get

$$2a=64\,k,$$

or

$$2a=64\times\frac{\text{Velocity}}{\text{Radius of curve}}.$$

This approximate formula applies only to the "shayo-sha," or ordinary non-bogie carriages, whose wheels have cylindrical tires. Investigations like these are useful in the discussion of the derailing of a carriage.



LATERAL VIBRATION PRODUCED BY "POINTS."

11. The express trains, to which the carriage "shayo-sha" was attached, passed through some of the different stations very quickly, the velocity being, except in two cases, greater than 30 miles per hour, and the highest being 48.5 miles per hour.*

The *points* on the Sanyo Railway have crossing numbers of 8 and 10, which correspond respectively to the crossing angles of 8°

* The velocities are given, as usual, according to the indications of the velocity-recorder, which are greater by about 2 miles per hour than the real values. (See Art. 2.)

and 10°. The two following tables, which relate respectively to the down and up trains, give the sudden lateral vibrations of the carriage experienced when crossing over the points at the different stations; the numerals put in brackets, (1) and (2), suffixed to the names of the latter, signify that the vibrations so marked were measured respectively before and after a station. The *a* and *2a* in the 3rd column have the same signification as in Art. 7. (Illustrative diagrams are given in Pl. VIII.)

TABLE XXI. SUDDEN LATERAL VIBRATION OF THE CARRIAGE PRODUCED BY *POINTS*. SANYO RAILWAY.

DOWN TRAIN.

Station.	Velocity.	Lateral Vibration.		*T*
		2a	*a*	
	miles/hour.	mm.	mm.	sec.
Kobe. (2)	20	33		—
Takatori. (2)	35	30		2.1
Suma. (1)	32	8		1.0
Shionoya.* (1)	40	42		—
Tarumi. (2)	42	102		—
Maiko.* (1)	42	44		—
Akashi.	44	90		—
Okubo.	32	50		—
Tsuchiyama. (2)	34	110		2.9
Kakogawa. (1)	46	135		2.9
Hoden.	47	46		—
Sone.	40	77		—
Gochyaku.	40	73		—

Station.	Velocity.	Lateral Vibration.		*T*
		2a	*a*	
	miles/hour.	mm.	mm.	sec.
Aboshi. (1)	32	......	152 132	3.2
" (2)	31	180;	95	—
Tatsuno. (1)	34	90		2.4
" (2)	34	140;	76	2.7
Nawa. (1)	34		76	—
" (2)	34	......	82 92	—
Aritoshi. (1)	38	small.		—
" (2)	38	100		—
(Arrives at Kamigori.)				
Mitsuishi. (1)	32	94;	86	2.2
" (2)	29	114 165		—
Yoshinaga. (1)	39	152;	76	—
" (2)	36	106;	68	—
Wage. (1)	34	144;	65	—
" (2)	31	86		—

* Cases of no crossing.

TABLE XXI. *Continued.*

Station.	Velocity.	Lateral Vibration. 2a	a	T	Station.	Velocity.	Lateral Vibration. 2a	a	T
	miles/hour.	mm.	mm.	sec.		miles/hour.	mm.	mm.	sec.
Mantomi. (1)	48	156;	79	—	Nagaoka. (1)	38	65		—
„ (2)	32	144;	132	—	„ (2)	33	42		—
Seto. (1)	35	167;	86	—	Okayama. (1)	27	160;	86	—
„ (2)	$32\frac{1}{2}$	—	128	—	(Arrives at Okayama.)				

TABLE XXII. SUDDEN LATERAL VIBRATION OF THE CARRIAGE PRODUCED BY *POINTS*.

SANYO RAILWAY.

UP TRAIN.

Station.	Velocity.	Lateral Vibration. 2a	a	T	Station.	Velocity.	Lateral Vibration. 2a	a	T
	miles/hour.	mm.	mm.	sec.		miles/hour.	mm.	mm.	sec.
Okayama. (2)	$23\frac{1}{2}$	(No effect.)		—	Kamigōri. (1) (Stops at Kamigori.)	25	56		—
Nagaoka. (1)	32	84		—	Kamigori. (2)	Slow.	(No effect.)		
„ (2)	30	95		—					
Seto. (1)	35	62		—	Aritoshi. (1)	35	129;	80	—
„ (2)	33	128;	74	—	„ (2)	32	106;	96	—
Mantomi. (1)	33	49		—	Nawa. (1)	$32\frac{1}{2}$	160		3.3
„ (2)	31	165;	78	—	„ (2)	32	154		—
Wage. (1) (Stops at Wage.)	34	79		—	Tatsuno. (1)	$32\frac{1}{2}$	148		1.9
Wage. (2)	Slow	(No effect.)			„ (2)	30	160		—
Yoshinaga. (1)	30	56		—	Aboshi. (1)	$33\frac{1}{2}$	25		—
„ (2)	28	107;	67	—	„ (2)	33	122		—
Arrives at Mitsuishi.	—	(No effect.)							

TABLE XXII. *Continued.*

Station.	Velocity.	Lateral Vibration.		T	Station.	Velocity.	Lateral Vibration.		T
		$2a$	a				$2a$	a	
	miles/hour.	mm.	mm.	sec.		miles/hour.	mm.	mm.	sec.
Himeji. (1) (Stops at Himeji.)	27	126		—	Kakogawa. (1)	40	132;	78	—
					,, (2)	38	104		—
Himeji. (2)	Slow.	(No effect.)			Tsuchiyama. (1)	$34\frac{1}{2}$	150;		—
Gochaku. (1)	47	88			,, (2)	33	132;	62	2.7
Sone. (1)	47	120;	59	—	Ōkubo. (1)	$35\frac{1}{2}$	31		
,, (2)	45	133		—	,, (2)	36	107;	67	—
Hoden. (1)	$48\frac{1}{2}$	102		1.9					
,, (2)	$48\frac{1}{2}$	94		1.3					

From the above two tables, it will be seen that at the two stations of Shioya and Maiko, where there is no crossing of the lines for the express train, no large lateral vibration was produced, as ought to be. For the rest of the stations, the single displacement a varied, for velocities between 27 and 39 miles per hour, from 44 to 180 mm. Some of the strongest lateral movements produced by *points* were as follows.

Station.	Velocity.	Lateral vibration. (Up train).			
		a	$2a$	T	Max. acc.
	miles/hour.	mm.	mm.	sec.	mm./sec.^{2}
Tatsuno.	$32\frac{1}{2}$	—	148	1.9	810
Hoden.	$48\frac{1}{2}$	—	102	1.9	560
,,	$48\frac{1}{2}$	—	94	1.3	1100
Tsuchiyama.	33	62	132	2.7	360

The lateral shocks produced by point crossings thus seem to be rather greater than those caused by ordinary *curves.* Further measurements with improved instruments are necessary for making a discussion of the effect of "curves" and "points" on the derailing of carriages.

EXPLANATION OF PLATES.

Pl. I. *Fig. 1. Relation between the velocity of the train and the vertical vibration of the carriage "shayo-sha."*

The velocity varied from 16 to 50 miles per hour, the mean maximum vertical vibration of about 3.5 mm occurring at the velocity of about 35 miles per hour. (Correction for the indicated velocity = −2 miles per hour.)

Pl. II. *Relation between the velocity of the train and the lateral vibration of the carriage "shayō-sha."*

Fig. 2. For vibrations of the II and III classes, or those whose periods are included between 0.61 and 1.17 sec.

The velocity varied from 15 to 53 miles per hour.

Fig. 3. For vibrations of the I class, or those whose periods are included between 0.22 and 0.59 sec. The velocity varied from 14 to 50 miles per hour.

Vibration Diagrams of the Carriage "Shayo-sha."

PLATES III TO V. VERTICAL VIBRATION, RECORDED NATURAL SIZE.

Pl. III. *Fig. 4. Down line; the train passed through the Mitsu-ishi Tunnel, the velocity varying from 22 to 30 miles per hour.*

The motion of the carriage in the tunnel was in this case not particularly different from that on the adjacent grounds. The experiments on the Tokaido Railway showed, however, that in several cases, the vertical vibration was markedly greater in a tunnel than on the neighbouring ground, due probably to the effect on rails of moisture and imperfect air circulation in the former.

A comparison of Pls. III and IV with Pl. V shows that the vertical vibration corresponding to the velocities of 20–30 miles per hour are sometimes more pronounced than that corresponding to such a high velocity as 47 or 48 miles per hour.

Pl. IV. *Figs. 7, 8 and 9. Specimens of the vertical vibration diagrams taken at high velocities of the train, on the down line.*

Fig. 5. Between Ōkubo and Tsuchiyama.

The velocity varied from 42 to 38 miles per hour.

Fig. 6. Between Tsuchiyama and Kakogawa.

The velocity was 48 to 47 miles per hour.

Fig. 7. Between Himeji and Aboshi.

The velocity was 47 miles per hour.

In fig. 7, the motion consisted essentially of quick vibrations of an average period of 0.21 sec., superposed by micro-tremors of an average period of 0.06 sec. In figs. 8 and 9, on the other hand, the motion consisted of slow vibrations of an average period of about 0.56 sec., superposed by micro-vibrations of an average period of 0.062 sec.

PLATES V AND VI. LATELAL VIBRATION, RECORDED HALF SIZE.

Pl. V. *Fig. 8. Down line. Before the Mitsu-ishi Tunnel.*

The velocity was 21–22 miles per hour.

The motion consisted, as is always the case with a carriage running at a low velocity, of comparatively quick vibrations, whose average period was about 0.51 sec.

Fig. 9. Between Seto and Nagaoka, Up Train.

The velocity was 40–41 miles per hour.

Fig. 10. Between Sone and Gochaku, Up Train.

The velocity varied between 51 and 53 miles per hour.

The two last figures illustrate the vibration of the carriage when running with a high velocity over a *straight* portion of the railway. Movements like those as marked *a* (fig. 12) and *b* (fig. 13) were felt strongly.

Pl. VI. *Lateral vibration of the carriage at high velocities.*

Fig. 11. Down train; between Himeji and Aboshi.

The velocity was 48 to 49 miles per hour.

Fig. 12. Up train; between Aboshi and Himeji.

The velocity was 46 miles per hour.

The two figures represent the vibration of the carriage when passing nearly one and the same portion of the railwa y namely, between 38 and $38\frac{1.5}{4}$ miles and between $38\frac{1}{4}$ and $37\frac{3.5}{4}$ miles, respectively for the down and up trains. In both cases, the motion was very strong, due probably to the softness of the soil on which the rails are laid.

Pl. VII. LATERAL VIBRATION OF THE CARRIAGE DUE TO "CURVES." UP TRAIN. HALF SIZE.

Fig. 13. Between Nawa and Aritoshi.

The velocity varied between 38 and 43 miles per hour.

This illustrates the case in which the carriage, running with a high velocity, 40 to 43 miles per hour, experienced comparatively small sudden lateral displacements at the beginning and end of a *curve*. The radius was in each instance 40 chains.

Fig. 14. Between Aboshi and Himeji.

The velocity varied from 43 to 50 miles per hour.

This figure illustrates the case in which large sudden lateral displacements were experienced by the carriage when running at a high velocity of about 48 miles per hour, at (or near) the beginning and end of a *curve*. The radius was 40 chains.

Pl. VIII. LATERAL VIBRATION OF THE CARRIAGE DUE TO "POINTS." HALF SIZE.

Fig. 15. Down Train; before the arrival at the Okayama Station.

The velocity decreased from 37 to 20 miles per hour. The carriage experienced violent lateral shakings when it crossed over a *point*, although the velocity was only about 27 miles per hour.

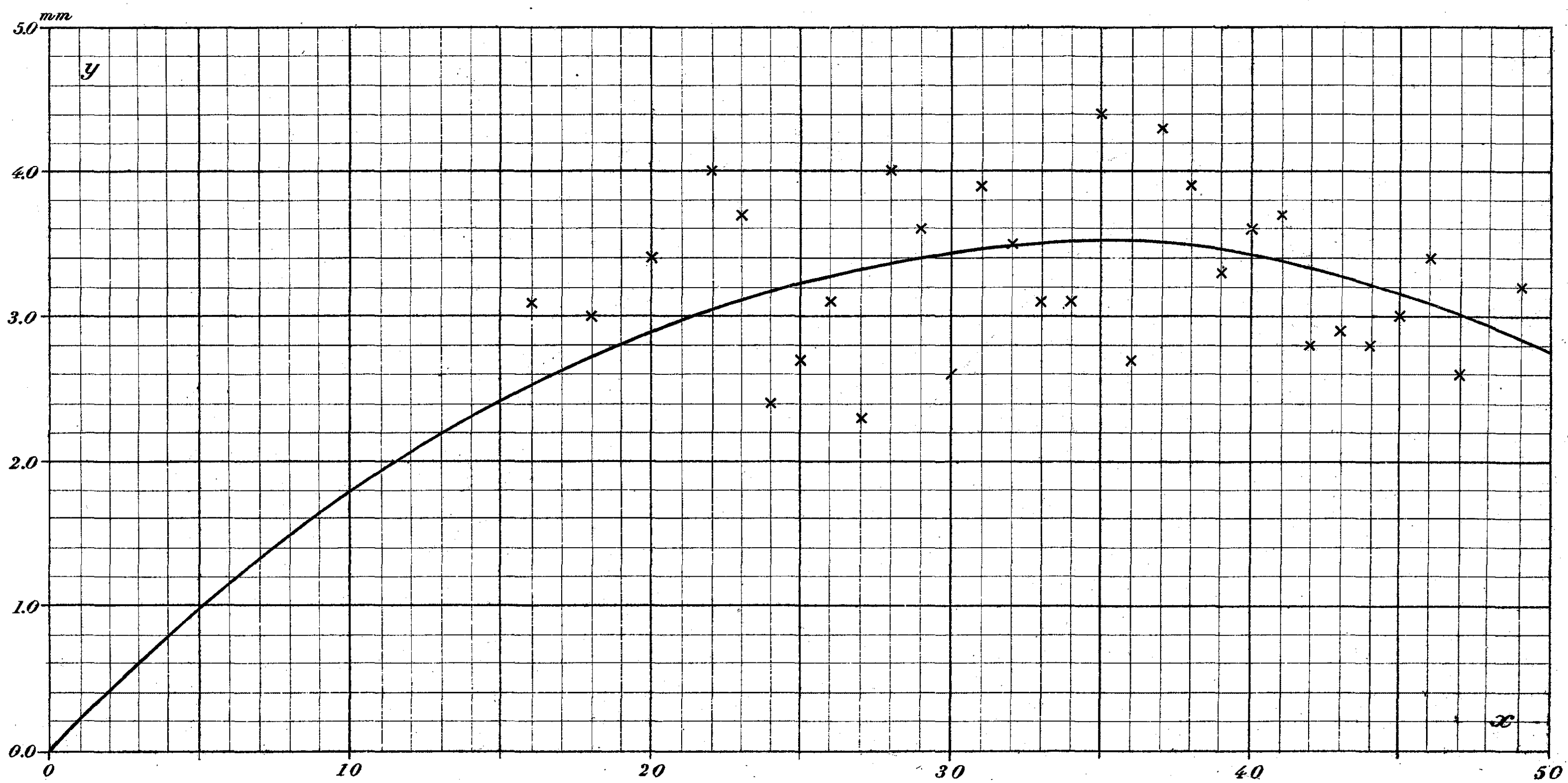
Fig. 16. Up Line; the Train passing through the Tatsuno Station.

The velocities, with which the carriage passed over the *points* before and after the station, were respectively about 33 and 30 miles per hour.

This figure illustrates the case where very large lateral shocks were produced by *points*.

Pl. I.

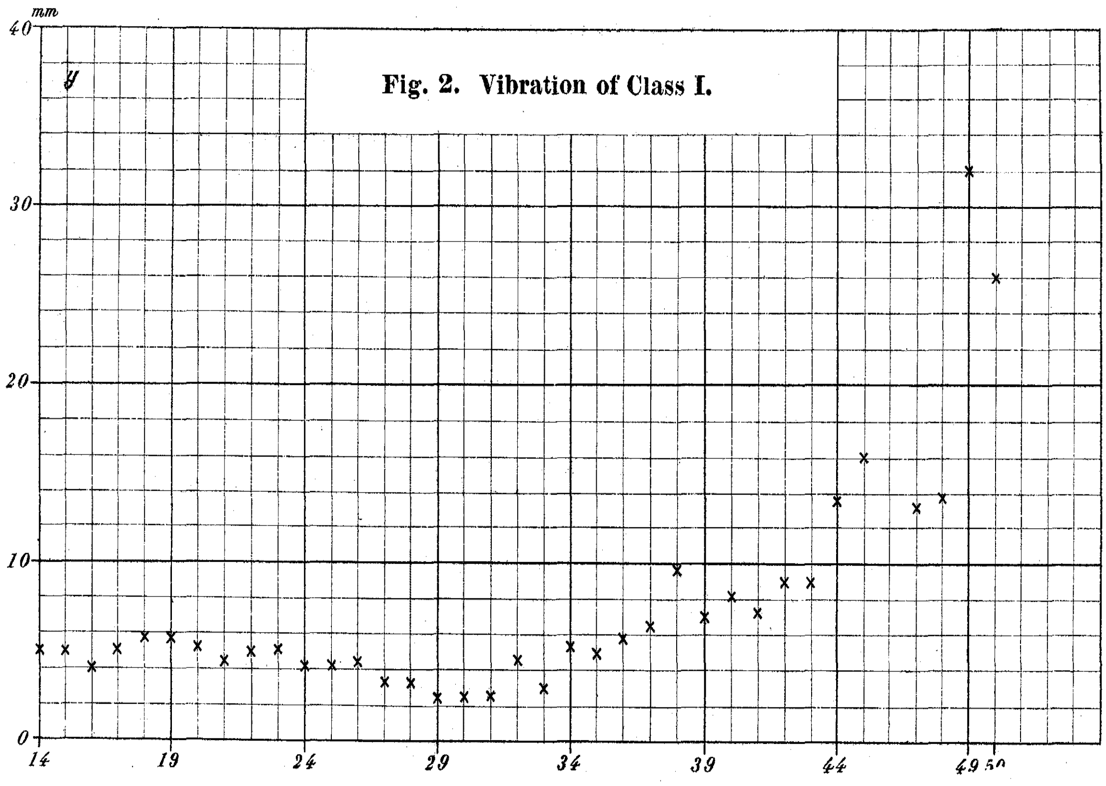
Fig. 1. Relation between the Velocity and the Maximum Vertical Motion of the Carriage. Down Train.

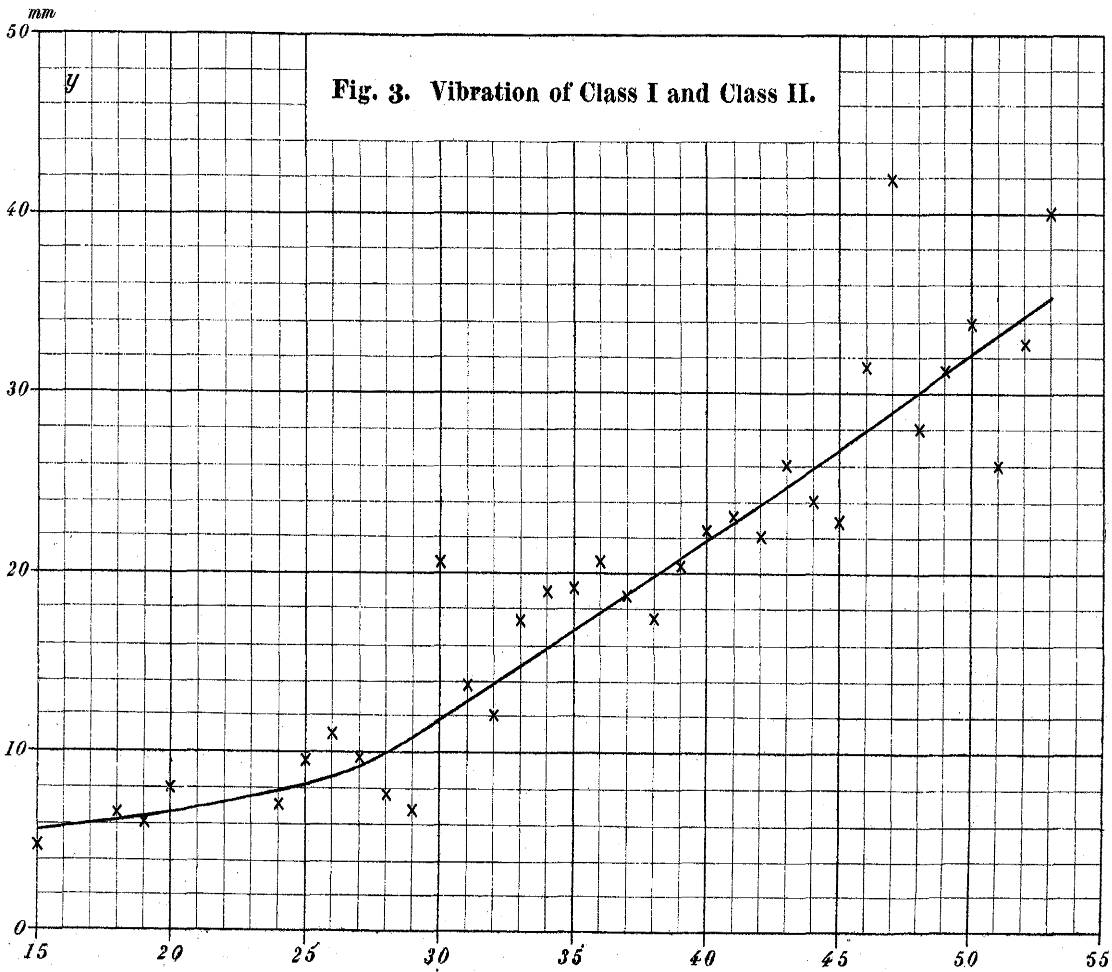


x=Velocity of the train, in miles per hour.

y=Lateral vibration of the carriage corresponding to x.

Relation between the Velocity of the Train and the Lateral Vibration of the Carriage.

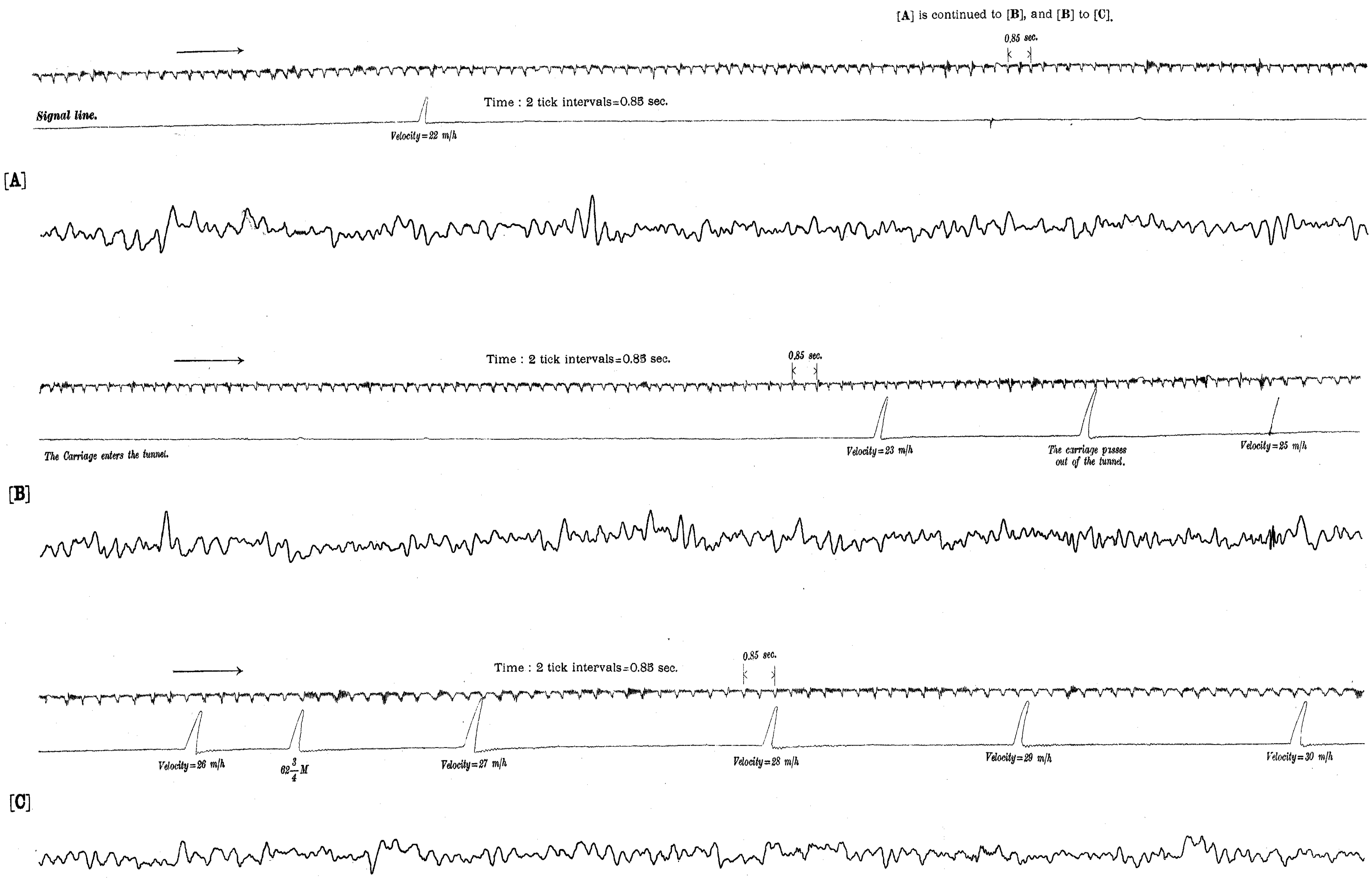




x= Velocity of the train, in miles per hour.
For figs. 2 and 3 : y= Maximum Lateral (average) vibration of the carriage corresponding to x.

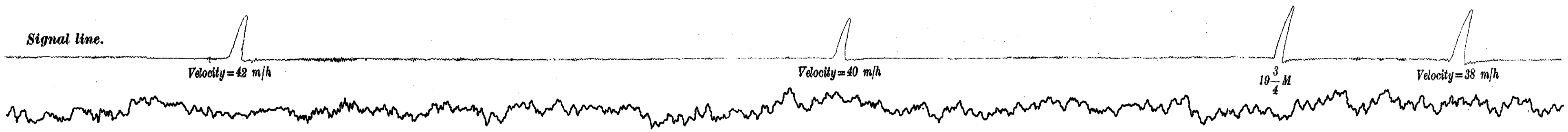
Fig. 4. Vertical Vibration of the Carriage "Shayo-Sha."

Natural Size. The Train passing through the Mitsu-ishi Tunnel. Down Train.



Vertical Vibration of the Carriage "Shayo-Sha" at high Velocities. *Natural Size.* Down Train.

FIG. 5 BETWEEN OKUBO AND TSUCHIYAMA.



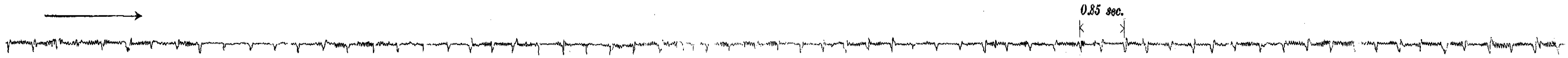


FIG. 6. BETWEEN TSUCHIYAMA AND KAKOGAWA.

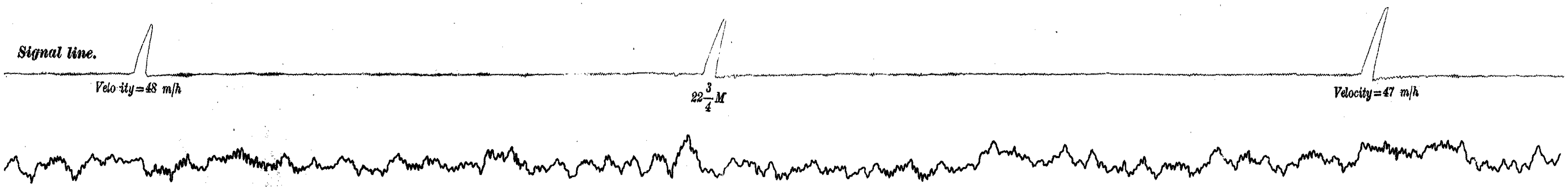


FIG. 7. BETWEEN HIMEJI AND ABOSHI.

Lateral vibration of the Carriage "Shayo-Sha." *Half Size*

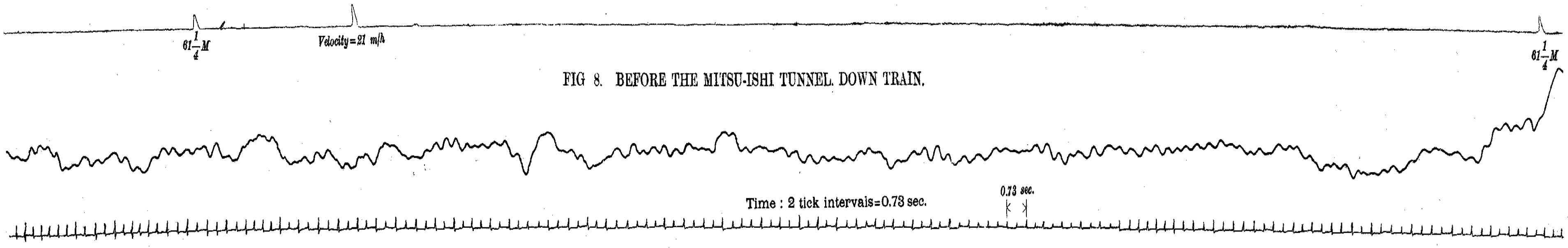


FIG 8. BEFORE THE MITSU-ISHI TUNNEL. DOWN TRAIN.

FIG. 9. BETWEEN SETO AND NAGAOKA. UP TRAIN.

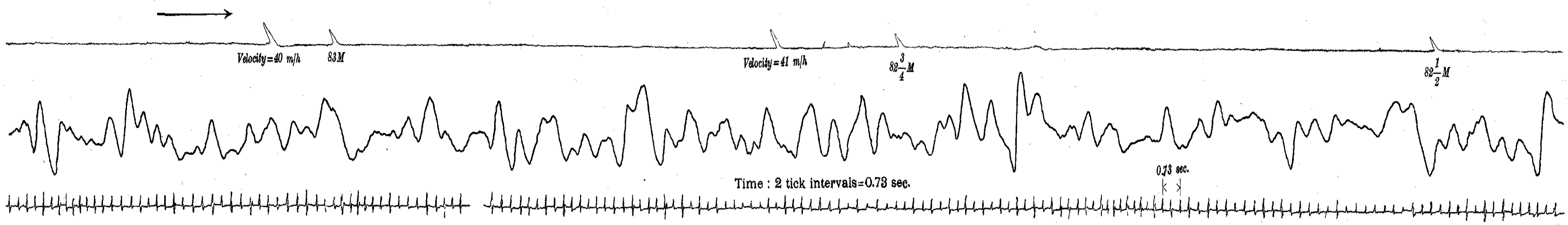
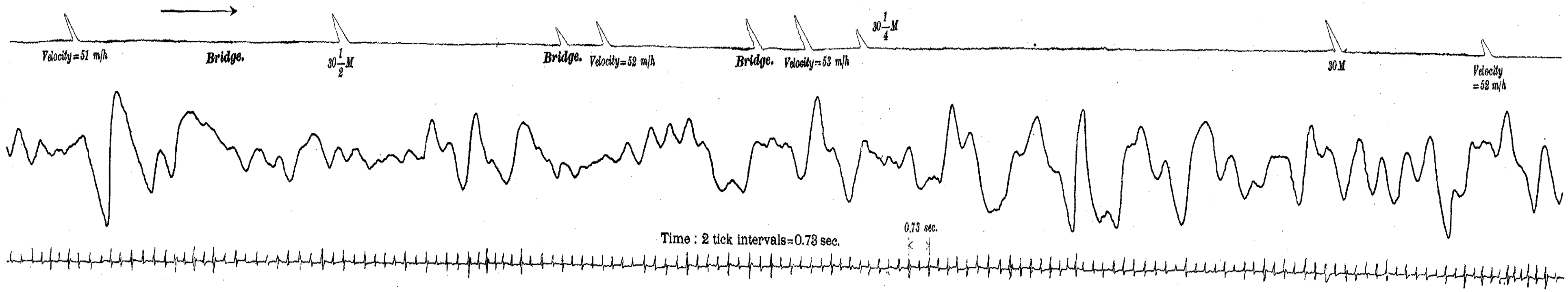


FIG. 10. BETWEEN SONE AND GOCHIAKU. UP TRAIN.



Lateral Vibration of the Carriage "Shayo-Sha" at High Velocities. *Half Size.*

Fig. 11. Down Train; between Himeji and Aboshi.

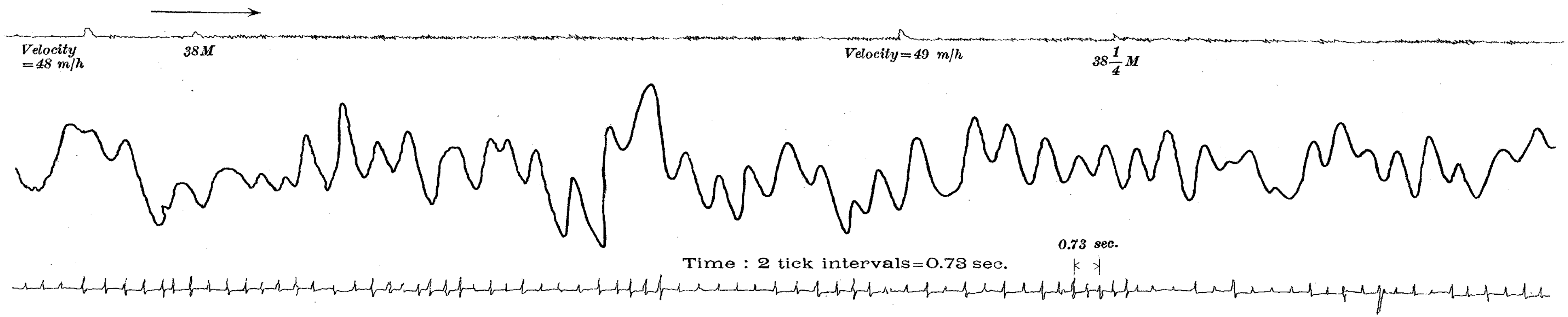
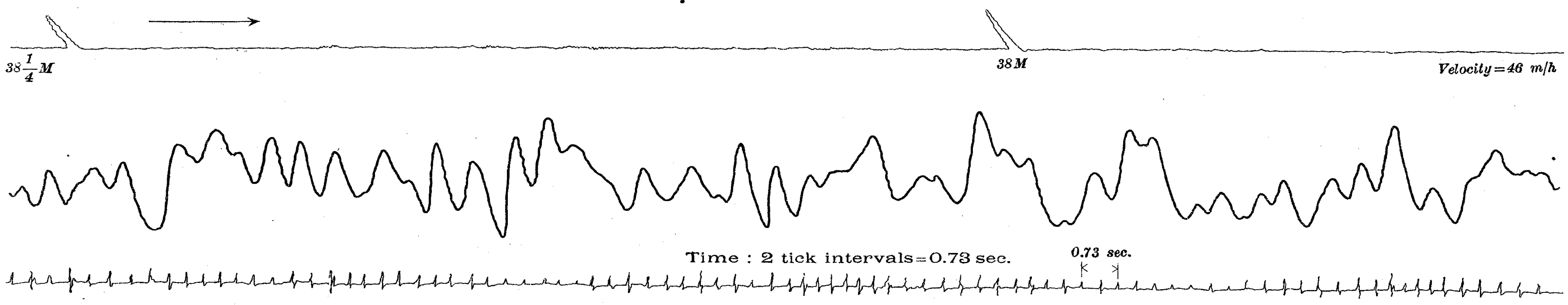


Fig. 12. Up Train; between Aboshi and Himeji.



Lateral Vibration of the Carriage "Shayo-Sha," showing the Effect due to *Curve*. Up Train. *Half Size.*

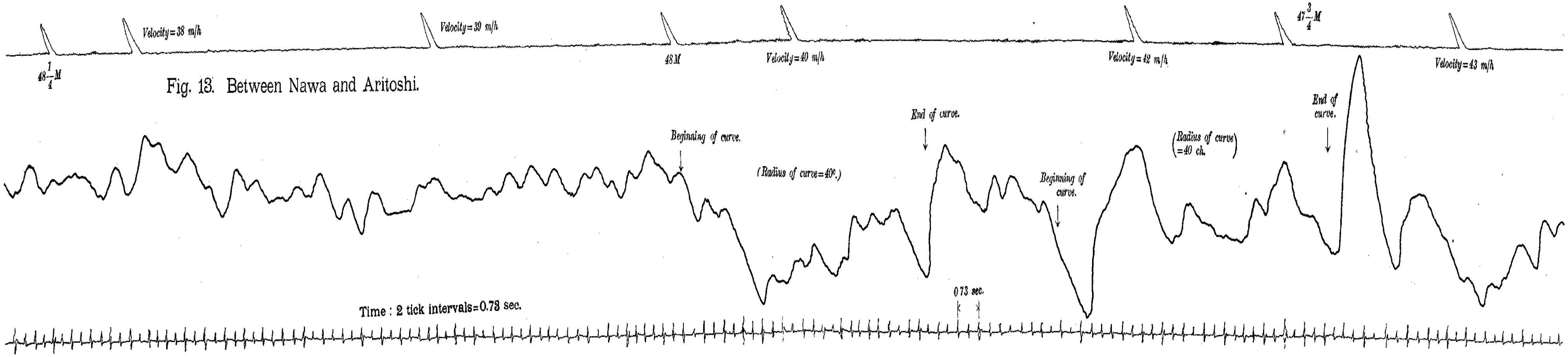


Fig. 13. Between Nawa and Aritoshi.

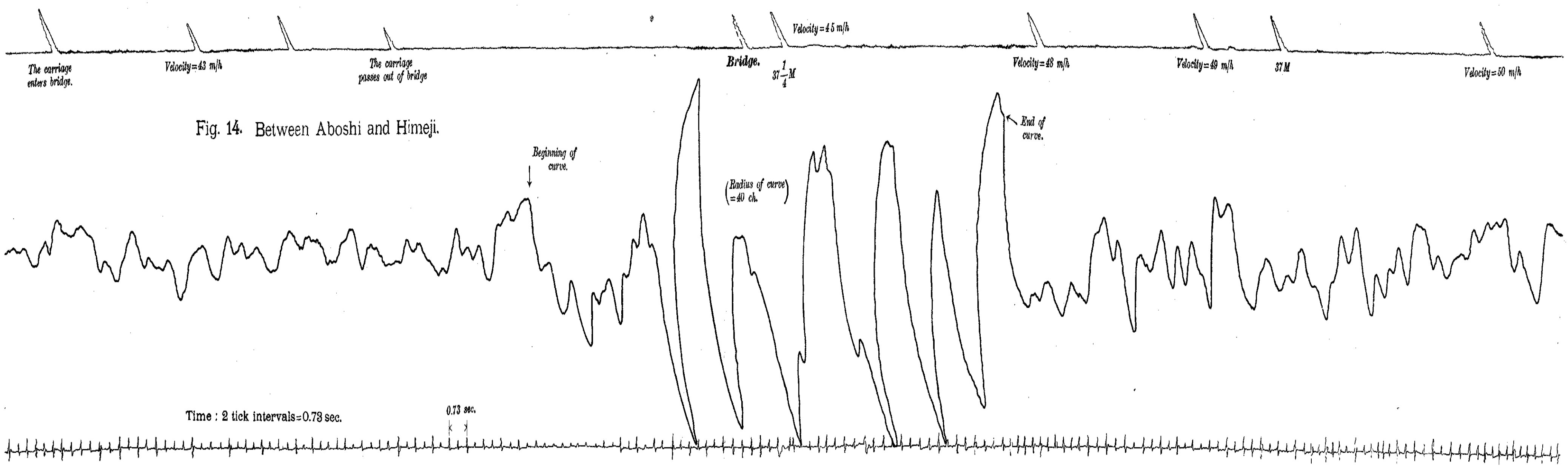


Fig. 14. Between Aboshi and Himeji.

Lateral vibration of the Carriage "Shayo-Sha," showing the Effects due to *Point.* *Half Size*

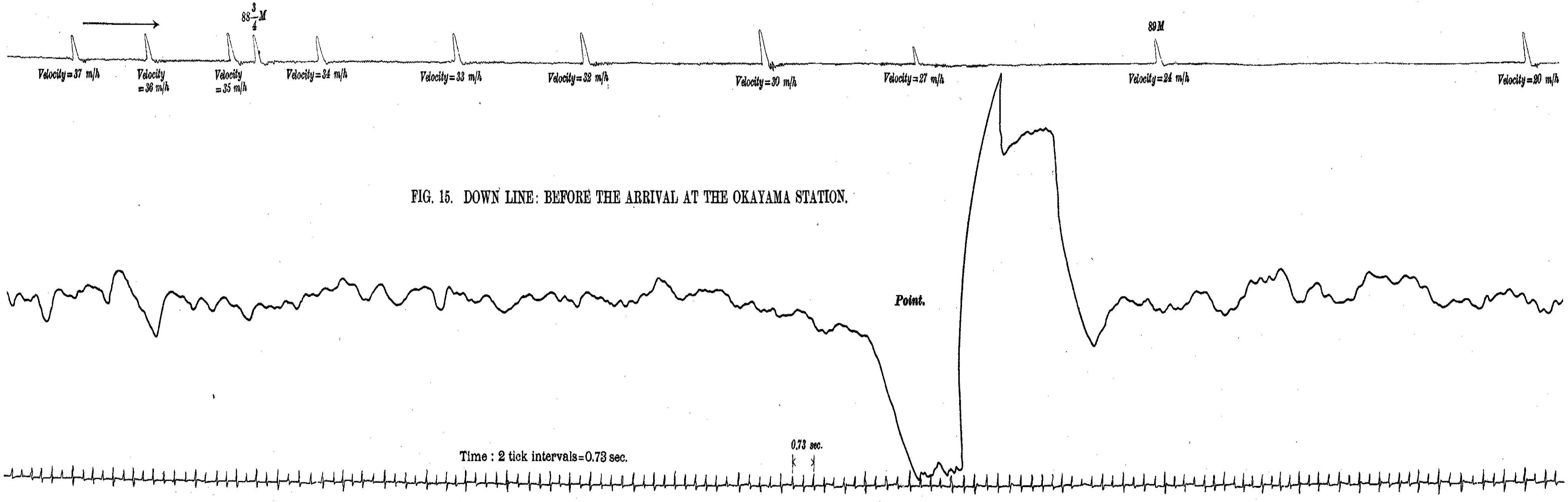


FIG. 15. DOWN LINE: BEFORE THE ARRIVAL AT THE OKAYAMA STATION.

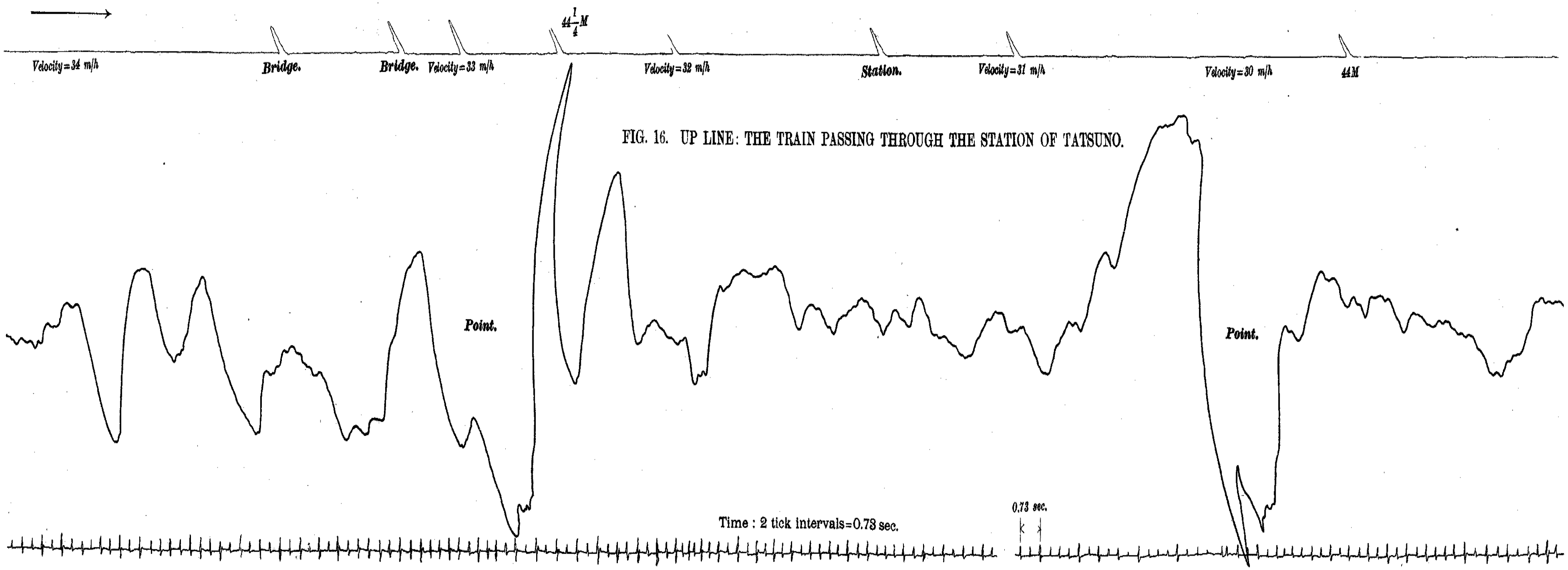


FIG. 16. UP LINE: THE TRAIN PASSING THROUGH THE STATION OF TATSUNO.