THE WAVEFORM OF ATMOSPHERICS AT NIGHT

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Summary—In order to study the change of waveforms of atmospherics with distance, the author discusses the waveforms, observed simultaneously at Toyokawa, Kumamoto and Akita Stations in Japan in 1952. They are classified into 5 groups according to the distance: A more than 4,000 km, B 3,000-4,000 km, C 2,000-3,000 km, D 1,000-2,000 km and E less than 1,000 km.

The investigation reveals that in A and B the waveforms depend mainly upon the characteristics of trajectories, in D and E upon activities in meteorological phenomena showing varieties so much, and in C nearly equally upon meteorological and propagational conditions.

In general, similar waveforms are observed in the distant ones over nearly equal kinds of trajectories, and the strikingly similar ones in the same phenomena at the same place and date. Dependence on the direction of propagation is not yet determined exactly.

1. Introduction

Some years ago the author published the results of an extensive study on the waveform of atmospherics observed in 1940–1944,[1] but it was mainly limited in the daytime. To investigate the effect of propagation on the waveform it is more useful to examine the waveform at night too.

Accordingly, since the autumn in 1952, the author has studied the waveform at night, and published a part of the results already.[2] In the present article, the study is chiefly directed to the correlation of waveform with distance, travelled by atmospherics, observed in winter of 1953, at Toyokawa (34°50′ N, 137°22′ E), Kumamoto (32°55′ N, 130°50′ E) and Akita (39°43′ N, 140°08′ E) simultaneously.

Direction finding and waveform observation were made at the same time so that the origins, derived from direction finding, may correspond surely to the waveform observed. In order to synchronize the measurements in 3 stations, we adopted the time signals, emitted for 20 ms at every second from the Standard Wave Transmitting Station in Tokyo, and recorded time marks on the film. Observation was made in the following time table.

At higher sensitivity.	At lower sensitivity.
0310–0312 J.S.T.	0320-0325 J.S.T.
0910–0912 〃	0920–0925 〃
1510-1512 〃	1520–1525 〃
2110-2112 〃	2120–2125 〃

2. Results of Observation

The origins of atmospherics was determined by triangulation from the directional observations at the three stations, and descrimination was made carefully among waveform records in order to select those coming from defined origins. The waveforms are clasified in 5 groups according to the distance from origins.

A. more than 4,000 km B. 3,000-4,000 km C. 2,000-3,000 km
D. 1,000-2,000 km E. less than 1,000 km

In the following, the characteristics of waveform are studied, based on meteorological conditions as well as trajectories of propagation.

A. More than 4,000 km

2100 J.S.T. 22 Feb. Similar waveforms 39′ and 40″ in Plate 1 come from origins in the Gilbert Islands[4] and those on the sea north of Java[3] respectively. Origins are considered to be thunderstorms or squalls over there. 39′ and 40″ are both smooth damped waves without superposed high frequency components, the latter being probably attenuated on long trajectories. The frequency of the first wave is about 14.5 kc/s and it decreases gradually to 5 kc/s at the 10th.

Either of the direction of their propagation is symmetrical to N-S direction, and so no dependence on the direction can be determined.[5]

Generally speaking, the waveform in A group depends more upon trajectories than on meteorological disturbances at origins. They show similar waveforms when they travel through the way of same properties.

B. 3,000-4,000 km

(1) **0000 J.S.T. 22 Feb.** Similar waveforms 28 and 40 in Plate 2, coming from origins in the inland of China and the mountain ranges in Burma respectively, are considered to be also due to thunderstorms there.[3] They are smooth damped waves without superposed high frequency components. The frequency of the first wave is about 15 kc/s and after 0.7-0.8 ms pause there appears successively second wave train. As this differs from the first, it is probably not emitted from multiple strokes.

Both of them come along the long way over the continent, and consequently the high frequency components are considered to be attenuated.

(2) **2100 J.S.T. 22 Feb.** Similar waveforms 33 and 37 in Plate 3, coming from origins in the mountain districts in Borneo, are assumed to be due to thunderstorms there. In each, the first wave train has weak high frequency components. It is followed by a second wave train of similar but smoother waves after about 0.6 ms pause. The second train is considered as multiple strokes.

Similar waveforms 44 and 44′ off the east coast of Borneo show superposed high frequency components. 33 and 37 are in the mountain districts, and 44 and 44′ on the sea. It is probably the reason why the latter contain smaller high frequency components than the former, depending on the difference of trajectories. The frequency of the first wave in the former is about 10 kc/s and that in the latter about 15 kc/s. 27‴ in the plain, north-eastern coast of Borneo, contains high frequency components, amounting between 33 and 44. It will probably be justified, if we assume attenuation in the plain to be intermediate between the mountain and the sea.

24 in Plate 4, coming from origins in the mountain district in Kwangsi, China, is a smooth damped wave whose frequency is 10 kc/s for the first, 9 kc/s for the second, and so on. Small high frequency components are considered to be due to strong attenuation over long trajectories on land.

(3) **2100 J.S.T. 17 Feb.** Waveforms 14 and 17 in Plate 5, coming from origins off the east coast of Borneo and Indo-China respectively, are similar damped waves with superposed high frequency components. It is probably because they have similar trajectories and generating conditions, though they are not in the same place.

In this region, waves, travelling over long land trajectories, are generally smooth damped waves, without superposed high frequency components due to attenuation; while those over sea rajectories are peaked complicated damped waves with abundant high freqnency components due to smaller attenuation.

There are some examples, in which the first train is followed by second or third train similar or not similar to the first, according as multiple strokes or other different strokes occur.

In any case, waves coming from similar geographical configuration are similar even not in the same day, while those coming from the same place in the same instant are surprisingly quite similar.

Dependence of waveforms upon discharge mechanism in origins is perceived only to a limited extent that similar or non-similar successive wave trains occur or not as explained above. The main controlling factor is probably the composition of trajectories, and in consequence we may assume strong surface waves, though the reflexion coefficient of lower ionosphere in winter night is large.[6]

C. 2,000–3,000 km

In this region meteorological conditions in origins are known and some of their characteristics are recognized in the waveforms.

(1) **2100 J.S.T. 22 Feb.** Similar waveforms 46 and 39″ in Plate 6 come from origins on the north and south side of a cold front respectively in Luzon Island, Philippine. Both of them are damped waves with superposed high frequency components, especially 39″ contains many high frequency successive wave trains. 12, 21 and 14 A, 25 come from origins on the sea east and west of Luzon Island respectively, apart a little from a cold front passing there, and their waveforms are smaller in scale than the former (46, 39″). As 14 A is near by 39″, so is the waveform more acitive than others.

(2) **0000 J.S.T. 22 Feb.** 2 in Plate 7 comes from origins in the cold front on the sea north-east of Luzon Island, Philippine. We observe waves due to leader strokes as well as main strokes, latter containing higher frequency components. 6 comes from origins on the sea north of New Guinea and south of the Typhoon Irma. It has nearly the same waveforms as that of 2, but it is accompanied by successive non-similar wave trains.

(3) **0000 J.S.T. 23 Feb.** 92 in Plate 8 comes from origins in the trough of 700 mb up-stream of the Yangtze River in the central mountain ranges of China. It has a damped wave with little high frequency components accompanied by a smooth damped wave trains. Frequency of the first wave in the first train is 15 kc/s and that in the second 8 kc/s. High frequency components are mostly attenuated on passing over a long land trajectory.

89 comes from origins on the sea west of the Typhoon Irma where the cold front changes itself into a stationary front. It contains a good deal of high frequency components corresponding to low attenuation over the sea trajectory. Suc-

cessive smooth waves may be the one from more distant origins, neither belonging to the typhoon nor to the cold front.

(4) 2100 J.S.T. 17 Feb. 8 and 18 in Plate 9 comes from origins on the cold front on the sea north-east of Hainan Island and Hongkong respectively. These waves contain high frequency components due to small attenuation over the sea trajectories.

(5) 2100 J.S.T. 20 Feb. 4, 105 and 107 in Plate 10 come from origins on the sea north, west-north-west and east of Luzon respectively. 4 is on the cold front, while 105 and 107 are on the north and south side of it. All waves contain high frequency components due to propagation over the sea.

(6) 0000 J.S.T. 20 Feb. 45 and 51 in Plate 11 come from origins in front of the trough in 700 mb in Kiangsi, China. They contain high frequency components.

In this region, the waveform depends on meteorological situations as well as propagation conditions. Waves, travelling mainly over continent, have a little high frequency component due to strong attenuation, while those passing over the sea keep a great deal of them.

Atmospherics, coming from active meteorological phenomena, such as troughs in the upper atmosphere, cold fronts, typhoons, etc., have large amplitudes and peaked waveforms, compared with those, coming from origins apart from active phenomena, even when they pass through the same trajectories.

In othere words, waveforms in this region depend upon discharge mechanism, frequency and strength of discharge, etc., as well as characteristics of trajectories or the nature of surface waves. Most of atmospherics have origins on the south-west quadrant of observatories, and so it is generally difficult to conculude the directional properties of trajectories.[5]

D. 1,000–2,000 km

In this region, there are sufficient data of meteorology, and most part of trajectories of propagation are on the sea. In consequence, waveforms depend principally upon meteorological conditions in origins.

(1) 0000 J.S.T. 23 Feb. 14, 85 and 69 in Plate 12 come from origins in the trough of 500 mb running along Ryûkyû to the east of Formosa, and the wind in 500 mb reaches 65 knots (Fig. 1). They are damped waves with plenty of high frequency components, their amplitudes being independent of distance.

74, 72 and 16 come from origins in the same district, but they are in small scale. It is probably because the former are emitted from more active parts along the trough and the latter from less active parts.

(2) 2100 J.S.T. 22 Feb. Waves in Plate 13 concern chiefly with the Typhoon Irma. 36′, 56 and 41 come from origins on the west and north side of the Typhoon respectively, origin of 41 being in the neighbourhood of the cold front. They contain high frequency components and 41 is most active.

6 and 6′ in Plat 14 come from origins in the trough of 700 mb which passes the sea south-east of Hokkaido Island. Inactive as they are, they contain also high frequency components. 30′ comes from the trough of 500 mb off the east coast of Formosa, and 31′ from showers near Chichijima Island. Both of them have similar waveforms but smaller, accompanied by successive wave trains. It

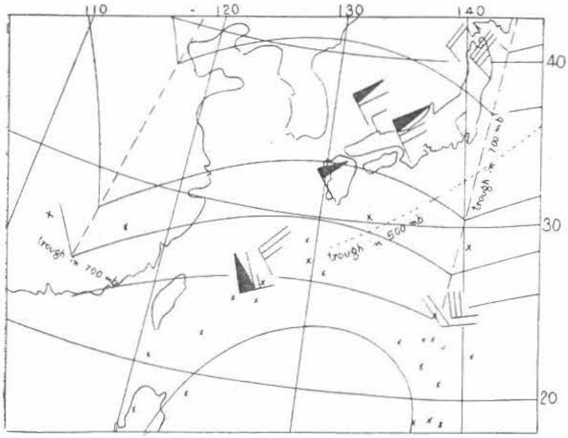

FIG. 1. Weather map in the upper atmosphere at 0000 J.S.T. 23 Feb., 1953.

is probably because they keep at a distance from disturbances.

(3) **2100 J.S.T. 17 Feb.** 11, 25, 7 and 21 in Plate 15 come from origins in the trough of 700 mb along the Ryûkyû Islands to Formosa, and 2 from the cold front south of Formosa. They are all similar damped waves with high frequency components.

(4) **0000 J.S.T. 22 Feb.** The trough of 500 mb passes Formosa, and the wind velocity in 500 mb is 75 knot (Fig. 2), 74, 70 and 54 in Plate 16 come from origins in this disturbed district and contain high frequency components. Among them 54 accompanies waves corresponding to leader strokes, while 74 is followed by successive wave trains due to multiple strokes.

(5) 2100 J.S.T. 19 Feb. Waveforms in Plate 17 come from origins on the East China Sea. Meteorological causes are not clear but it seems that disturbances due to invasion of cold air masses blown from the high pressure in the central part of China into warm air masses on the warm current of the East China Sea. These waves propagate mainly on land and so waveforms 57, 32 and 96, 13 m are all smooth damped waves loosing high frequency components due to attenuation over trajectories on land.

(6) 2100 J.S.T. 21 Feb. 37, 32 and 8 in Plate 18 come from almost the same origins as **(5)**, but in the present case we observe a cold front clearly as a result of disturbances mentioned above. They contain high frequency components and are very active, corresponding to stronger disturbances.

In this region waveforms depend much more upon meteorological disturbances in origins than on characteristics of trajectories. For example, even waves coming from the same place, such as the East China Sea, are peaked waveforms with much high frequency components when it is heavily disturbed, while they are smooth damped waves without high frequency components when it is less disturbed. However, waves coming from China or its coast are generally smooth damped waves due to attenuation over long land trajectories.

As to meteorological phenomena, active waveforms of atmospherics in this region originate mainly from troughs in the upper atmosphere, cold fronts, typhoons,

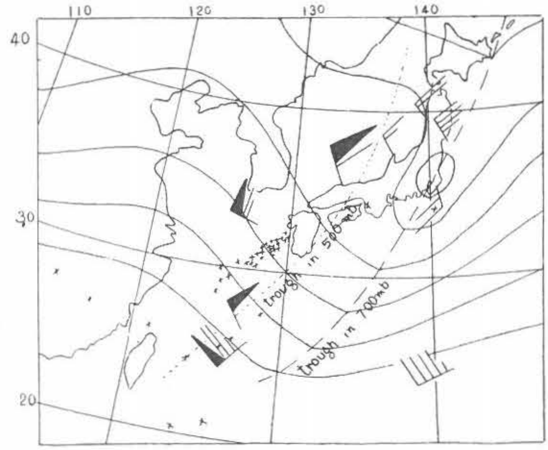

FIG. 2. Weather map in the upper atmosphere at 0000 J.S.T. 22 Feb., 1953.

thunderstorms and showers, and are generally peaked damped waves rich in high frequency components due to short trajectories, and the nearer the origins to disturbances, the stronger is the amtospherics.

Most of atmospherics come from the Ryûkyû Islands and the South China Sea, i.e. they are kept in the south-west quadrant of observatories, so the directional properties of waveforms can not be easily determined.[5)]

E. Less than 1,000 km

In this region there are many origins in Japan in which we have individual meteorological data in detail in addition to cold fronts, troughs in the upper atmosphere, and furthermore, the main features of waveforms of atmospherics are determined by meteorological disturbances rather than characteristics of trajectories.

(1) **2100 J.S.T. 22 Feb.** 32 and 4 in Plate 19 come from origins in the trough of 500 mb in the Ryûkyû Islands, and are damped waves of long duration with a lot of high frequency components (Fig. 1). 31 and 8, coming from the trough of 700 mb in Chichijima Island and in Iôjima Island respectively, are damped waves with high frequency components. In spite of a longer trajectory than that of 31, 8 is more active due to heavier disturbances in its origin.

37′ in Plate 20, coming from hail storms in the mountain ranges of Kantô District, consists of many successive wave trains. 7, 41 and 36, coming from snow showers and hail stroms off the north coast of Honshû Island, have similar waveforms with 37′, but smoother due to longer land trajectories.

(2) **0000 J.S.T. 22 Feb.** Among many waveforms, coming from origins in the trough of 500 mb in the Ryûkyû Island (Fig. 2), 4 representative wave groups are shown in Plate 21. 23, 58, 63, 12 and 11 are damped waves rich in high frequency components followed by many successive wave groups. 66 and 3 are also similar waveforms, accompanied by smooth sine waves of about 5 kc/s. 62′, 57 and 59 consist of smooth sine wave groups of about 5 kc/s with intervals of nearly 1 ms. 57 and 74″ are damped waves with small amount of high frequency components followed by smooth wave trains of 5 kc/s. Those waveforms, coming from the Ryûkyû Islands or China, are generally smooth damped waves of return stroke type due to long trajectories over land.

(3) 2100 J.S.T. 19 Feb. 58, 63, 47 and 28 in Plate 22, coming from origins along the trough of 700 mb on the sea south-west of Kii Peninsula (Fig. 3), are slightly peaked smooth damped waves of which the frequency of first wave is 17 kc/s and the amplitude decreases very quickly to the 6th. 97 in the same region has a complete waveform peculiar to the fall of thunderbolts, *i.e.* from leader strokes to return strokes and after glows. The frequency of the first wave is about 10 kc/s.

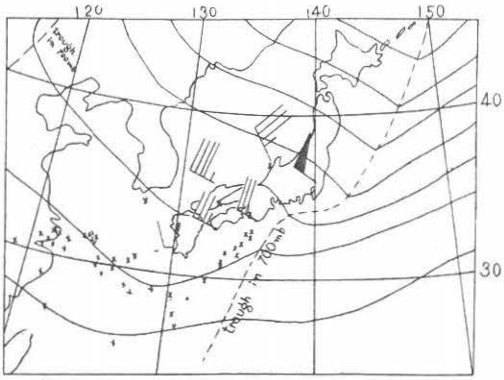

FIG. 3. Weather map in the upper atmosphere at 0000 J.S.T. 20 Feb., 1953.

(4) 0000 J.S.T. 23 Feb. Waves in Plate 23 come from origins along the trough of 700 mb passing through Hachijojima and Iôjima Islands (Fig. 1). 26 and 48 are damped waves with a plenty of high frequency components accompanied by smooth wave trains. 1, 2 and 8 are followed by much smoother wave trains. 99 in Hachijojima Island are the smoothest sine waveforms of about 5 or 6 kc/s with small damping.

(5) 0000 J.S.T. 18 Feb. and 2100 J.S.T. 17 Feb. 15 and 12 on 18th and 19 and 21 on 17th in Plate 24, coming from origins along the trough of 700 mb in the Ryûkyu Islands and on the East China Sea, are all similar peaked damped waves.

(6) Similar smooth wave trains There are many smooth damped waveforms mainly coming from China or its neighbourhood as shown in Plate 25, disturbances in their origins being sometimes unknown. 35 at 2100 J.S.T., 19 Feb. In Chosen Canal, 29 at 2100 J.S.T., 22 Feb. on the east coast of China, 14 at 2100 J.S.T., 22 Feb. on the north coast of Honshû Island from showers, and 66′ at 0000 J.S.T., 22 Feb. on the sea off the east coast of Honshû Island between cold and warm fronts—these are all smooth damped wave trains mainly due to attenuations over land trajectories.

In this region waveforms are generally determined by discharge mechanism, frequency of discharge, scale of discharge, and not so much controlled by the trajectories. This may be due to small travelling distances, especially over the sea. Various kinds of waveform are consequently observed, depending upon characteristics of disturbances in origins. Sometimes we can trace the complete set of waveforms concerning the fall of thunderbolts from leader strokes to return strokes and after glows. Waveforms coming from snow storms, snow showers, showers, hail storms are not yet definitely concluded due to scanty informations. Atmospherics, passing over the mountain ranges, have generally smooth waveforms even in the short distance due to heavy attenuation over the mountains.

Generally speaking, in this region waveforms are mainly controlled by the surface waves, scarecely by the reflected ones in the ionosphere.[5)6)]

3. Conclusion

This paper discusses the general characteristics of waveform of atmospherics in winter night. Though the reflexion coefficient of ionosphere for very long waves is believed to be relatively large,[6)] yet the surface wave is very strong and indicates no directional properties due to reflected waves.[5)]

The author classified waveforms into 5 groups according to distance: A. more than 4,000 km; B. 3,000–4,000 km; C. 2,000-3,000 km; D. 1,000-2,000 km; E. less than 1,000 km. Detailed investigation was made in each group and the following conclusion is derived.

In group C the influence of both the disturbances in origins and the characteristics of trajectories are nearly equally efficient, while in groups A and B the effects of propagation conditions predominate the other, and in groups D and E, on the contrary, the characteristics of disturbance determine nearly the overall features, and consequently there appear many varieties of waveforms, sometimes a complete form of the fall of thunderbolts being exemplified in the waveform, *i.e.* from leader stroke to return streamers and after glows. Specifically in group E the waveform depends exclusively upon disturbances, not on distance, and waveforms of atmospherics are generally determined by activities of thunderstorms, showers, snow showers, snow storms, cold fronts and troughs in the upper atmosphere.

It is also admitted that similar waveforms are obtained in the distant one as in group A and B when they come from nearly the same kind of trajectories and the strikingly similar waveforms in the same phenomena at the same place and date.

4. Acknowledgement

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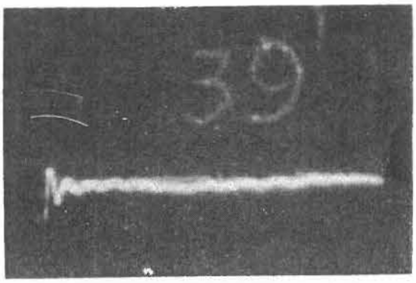
References

1) A. Kimpara: J. Geomag. Geoele. Jap. **1**, No. 1, 1949.
A. Kimpara: Memoirs Fac. Eng. Nagoya Univ. **1**, No. 1, 1949.
A. Kimpara: Proc. Res. Inst. Atm. **1**, p. 1, 1953.
2) A. Kimpara: Bul. Res. Inst. Atm. **3**, 1952.
3) A. Kimpara: Memoirs Fac. Eng. Nagoya Univ. **2**, p. 66, 1950.
4) J. J. Vaury et R. Bost: Note Préli. L.N.R. No. 156, 1952.
5) F. A. Kitchen: P.I.E.E., 100, Part III, p. 100, 1953
6) R. N. Bracewell: P.I.E.E., **98**, Part III, p. 221, 1951.

Plate 1

39′



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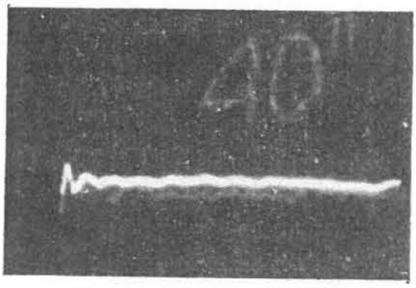

Plate 2

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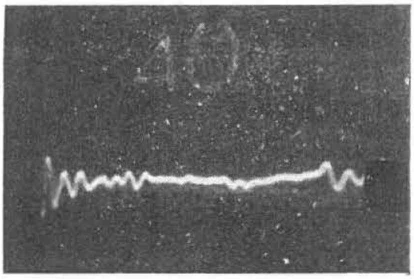

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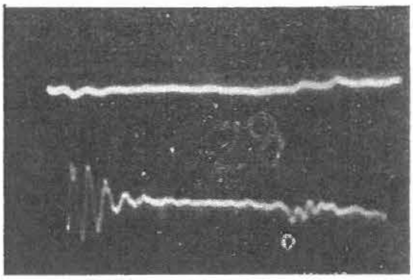
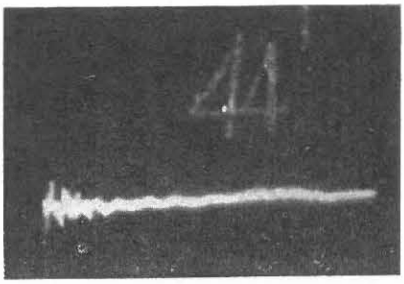


Plate 3

44′



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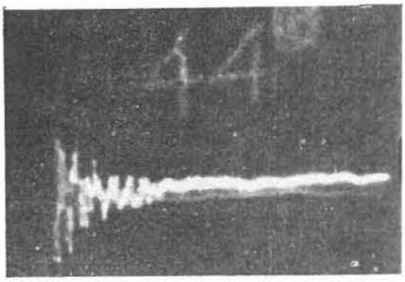

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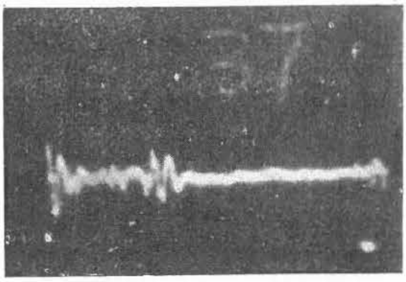

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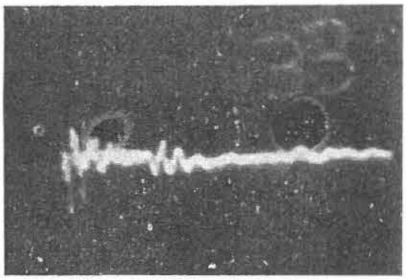

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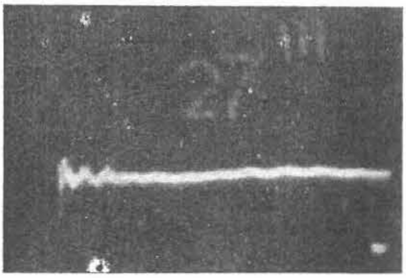

PLATE 4

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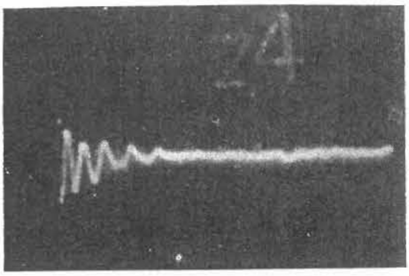

PLATE 5

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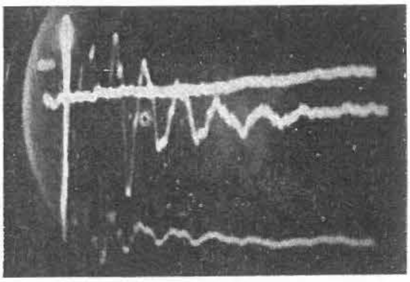

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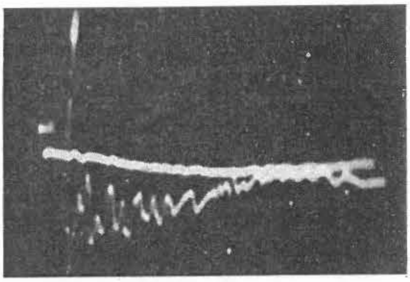
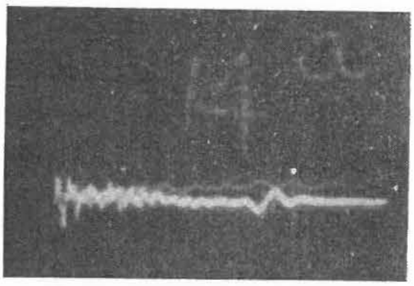


PLATE 6

14A



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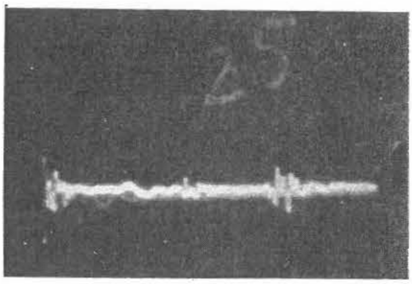

PLATE 6

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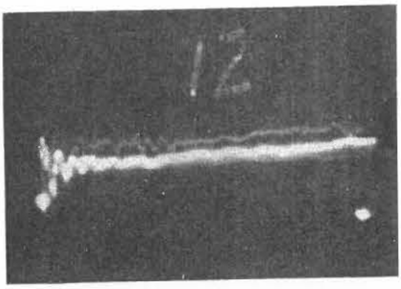

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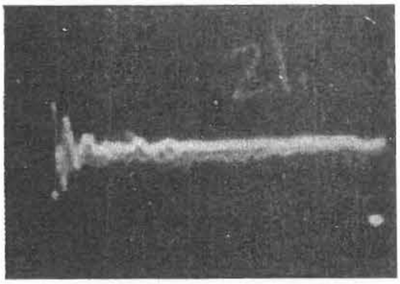

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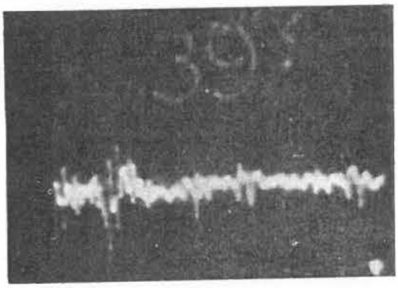

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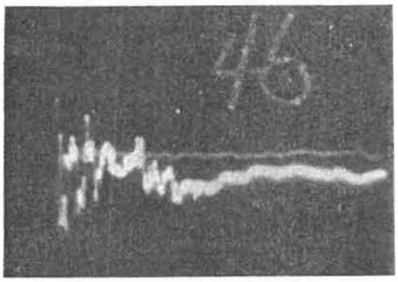

PLATE 7

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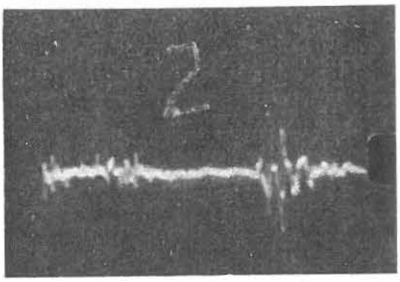

PLATE 7

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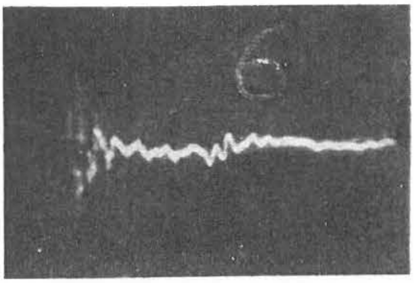

PLATE 8

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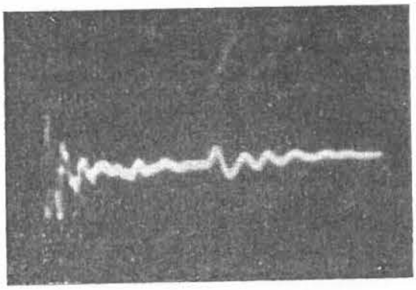

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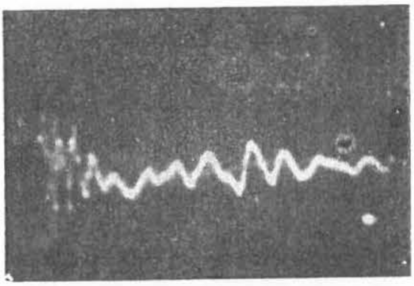

PLATE 9

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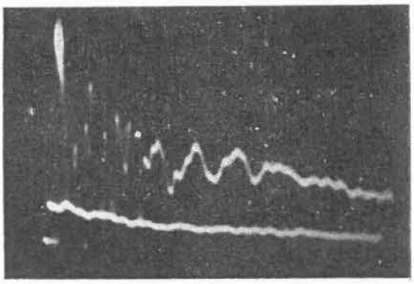

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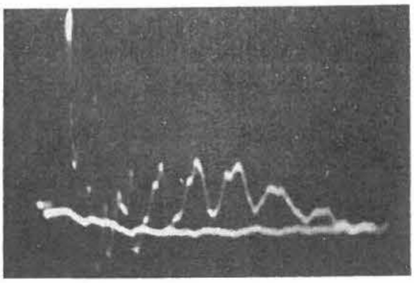

PLATE 10

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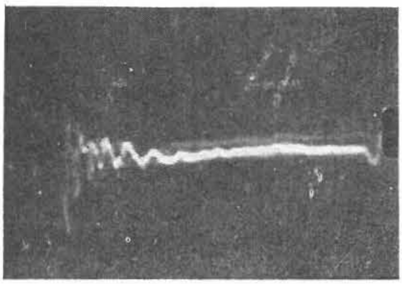

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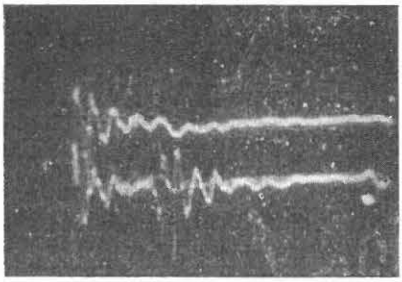

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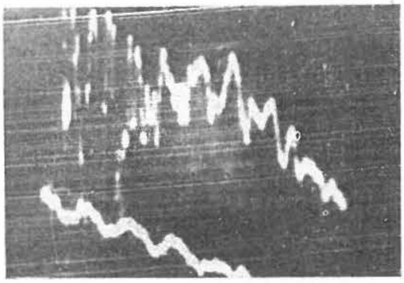

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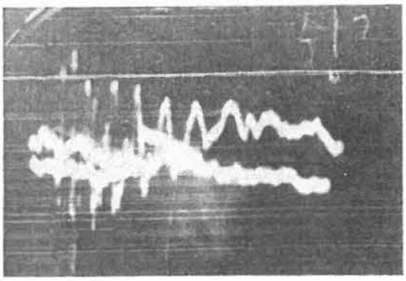

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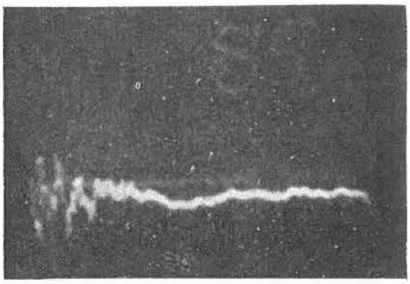

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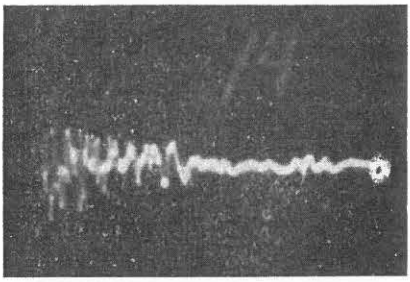

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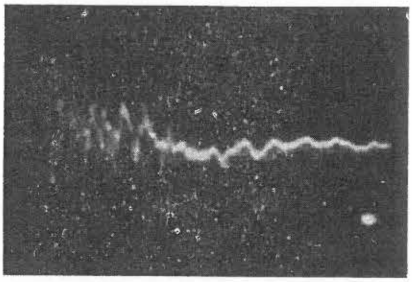

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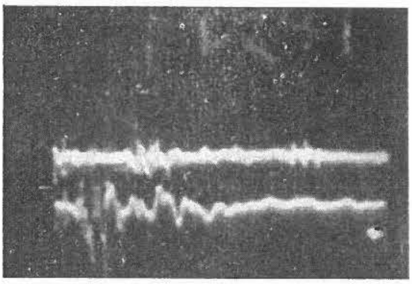

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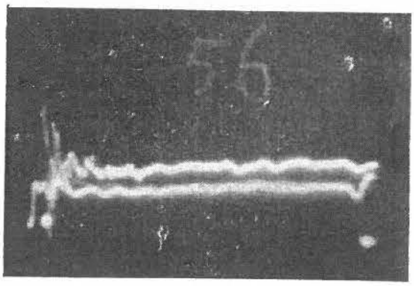

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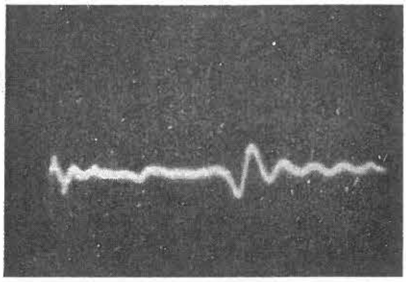

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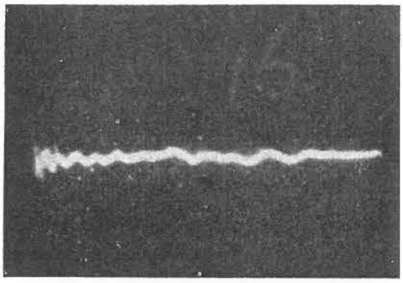

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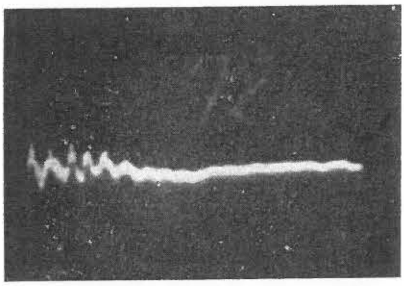

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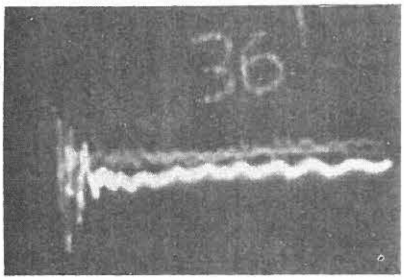

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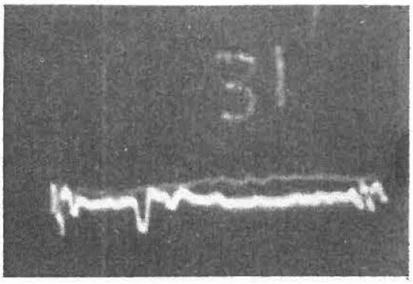

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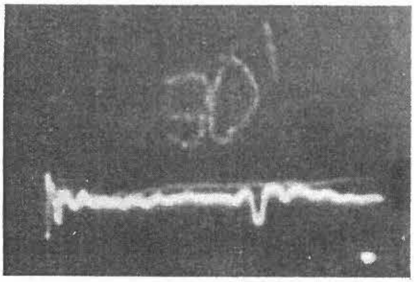

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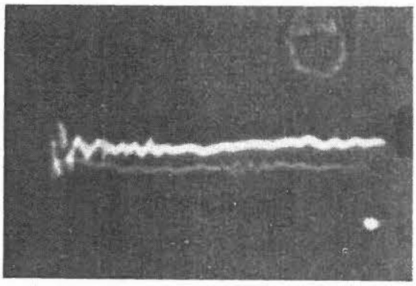

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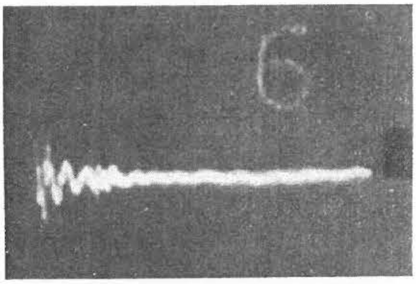

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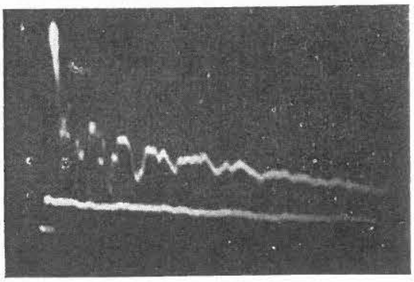

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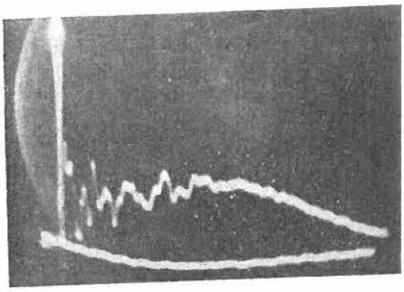

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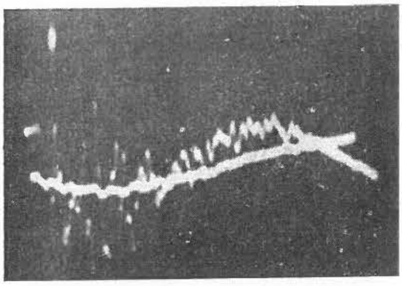

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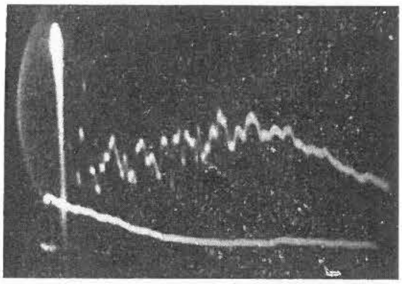

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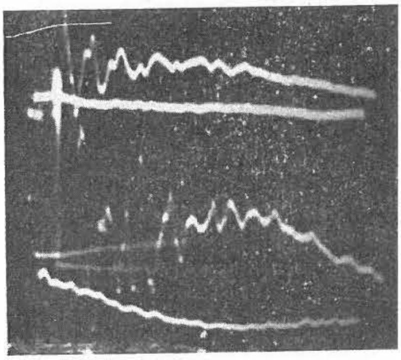

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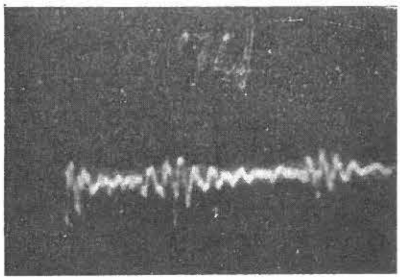

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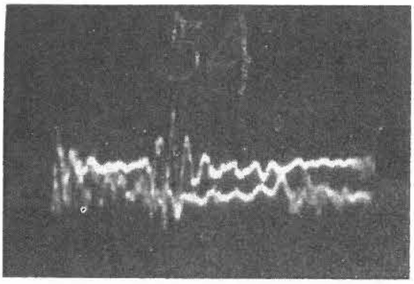

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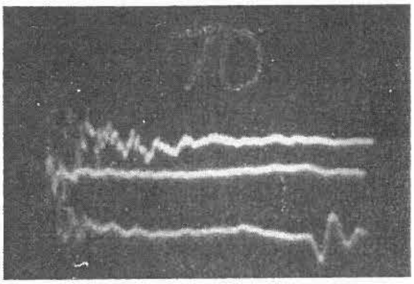

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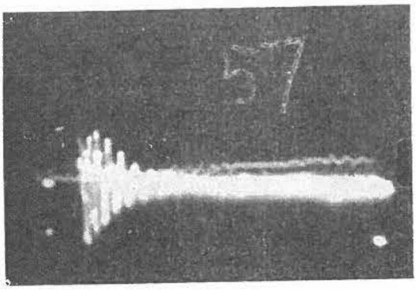

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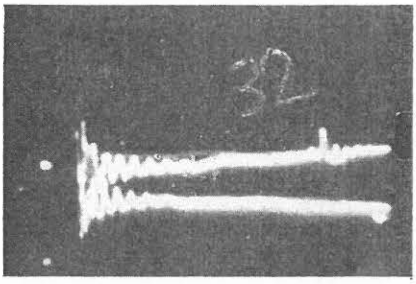

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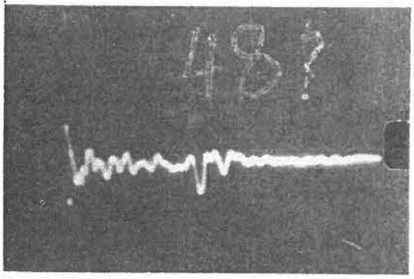

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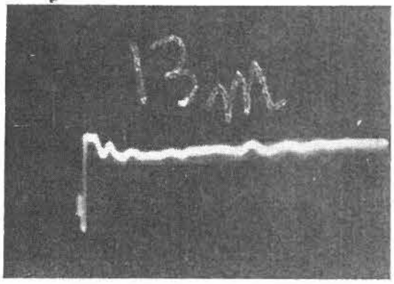

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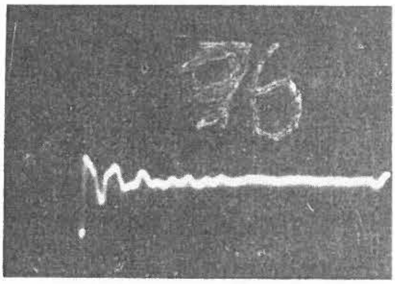

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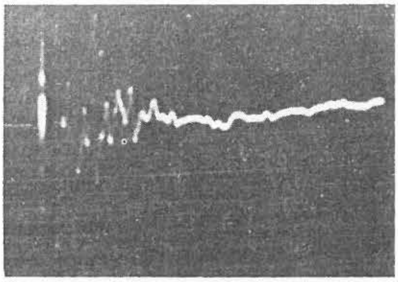

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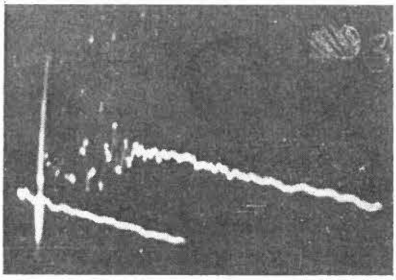

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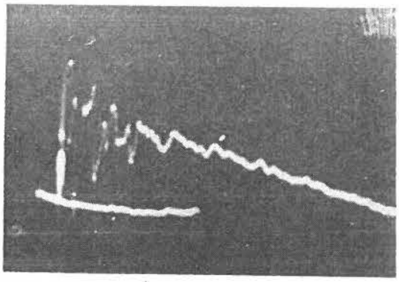

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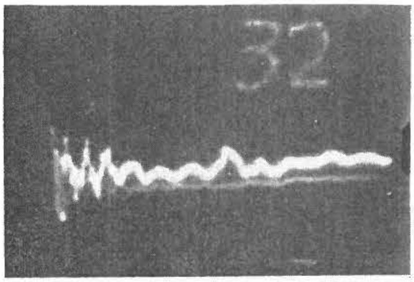

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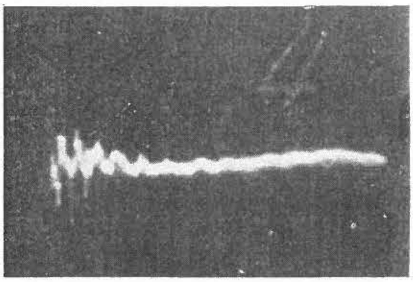

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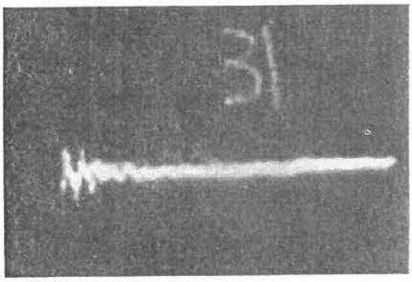

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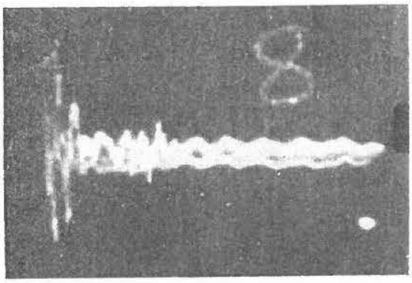

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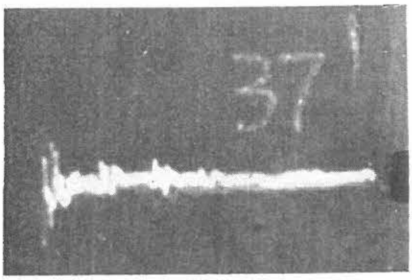

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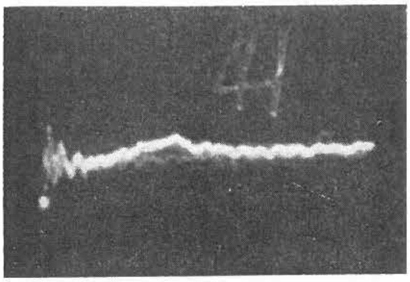

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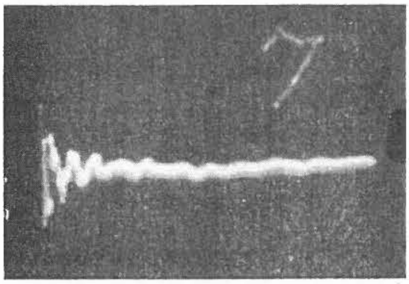

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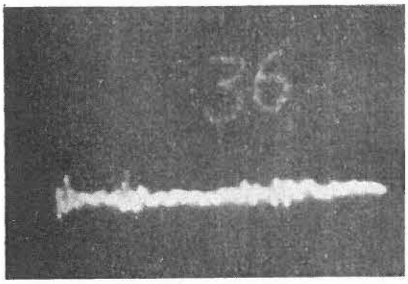

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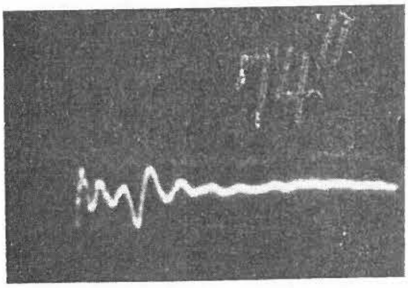

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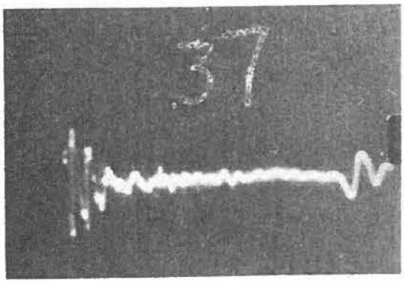

PLATE 21

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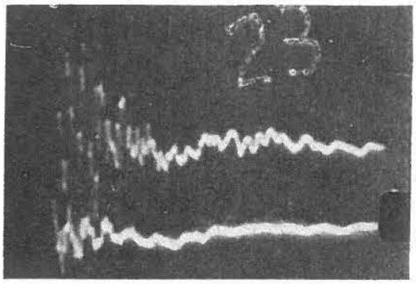

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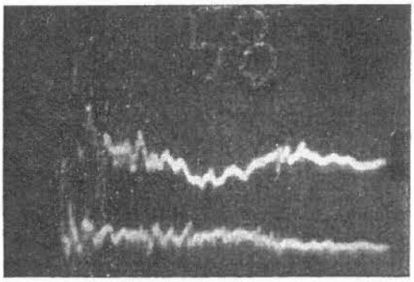

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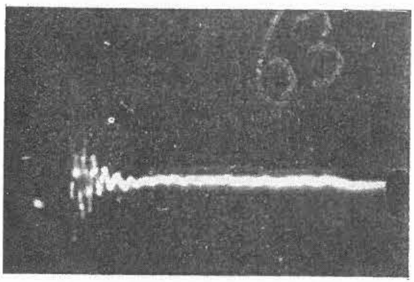

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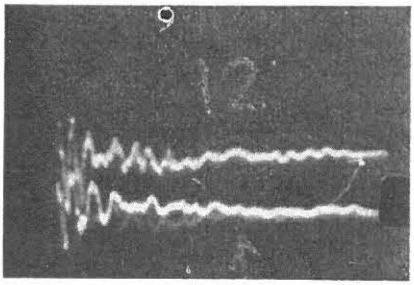

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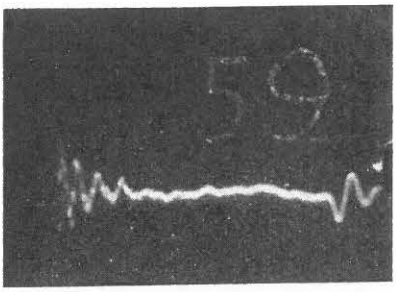

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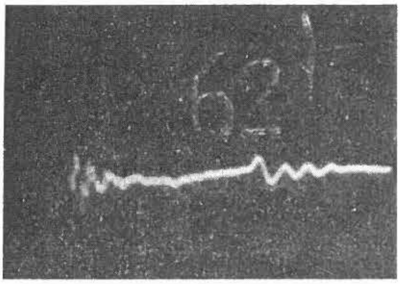

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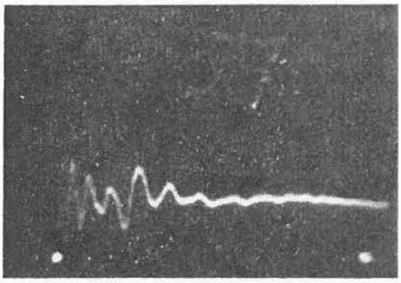

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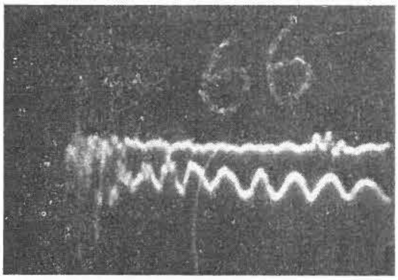

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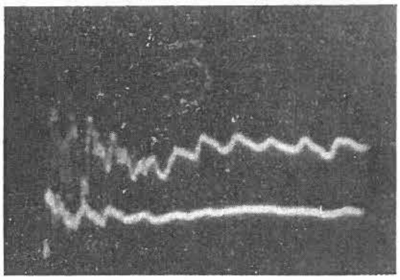

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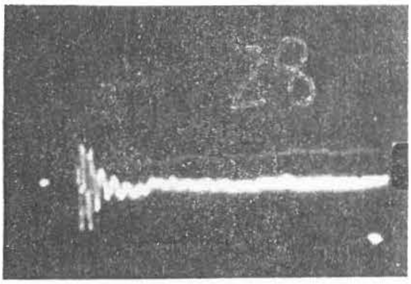

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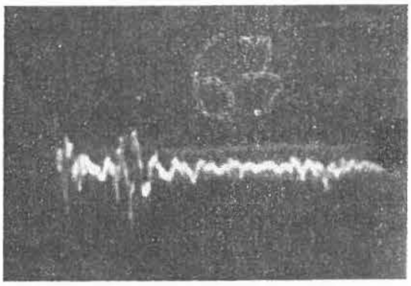

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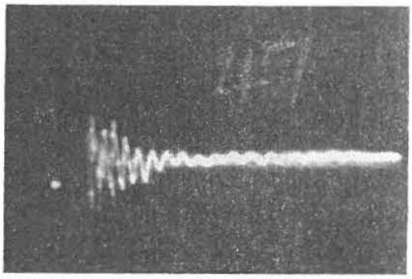

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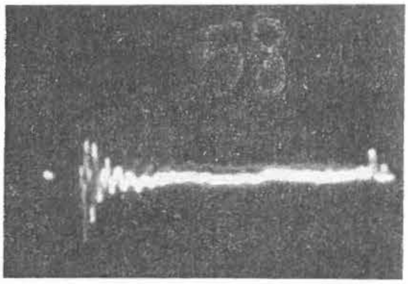

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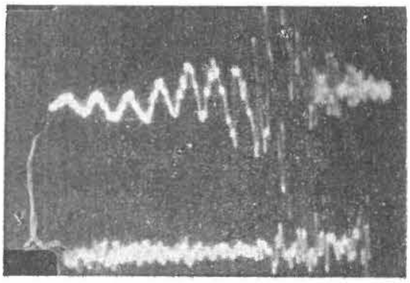

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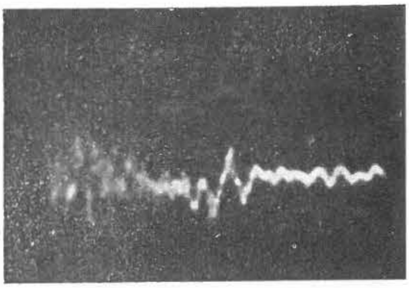

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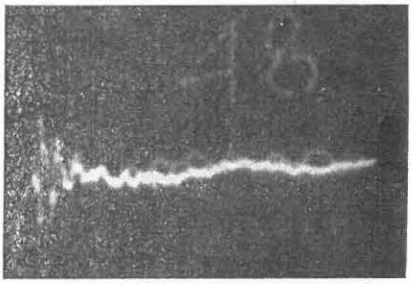

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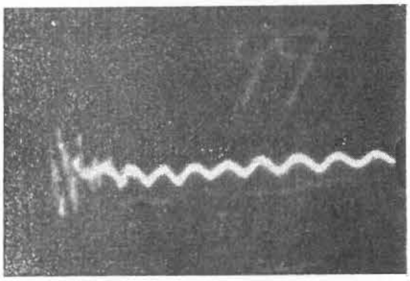

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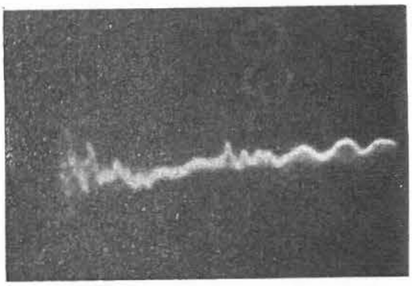

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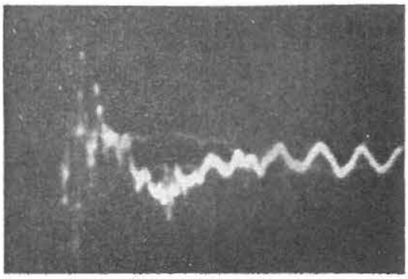

Plate 24

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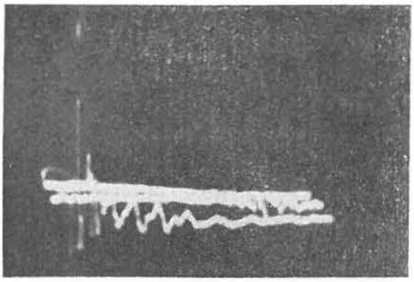

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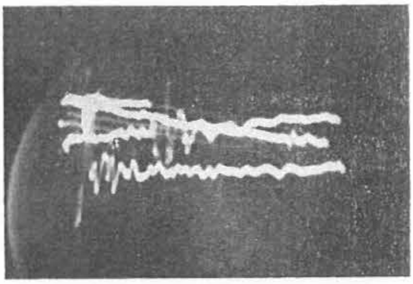

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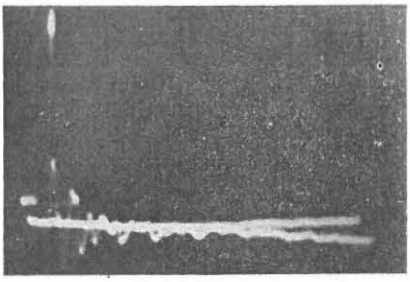

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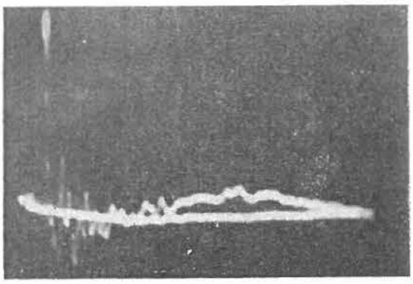

Plate 25

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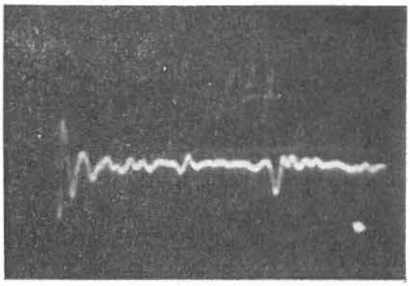

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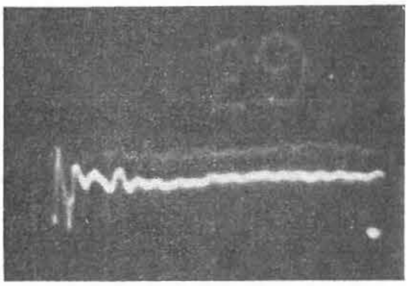

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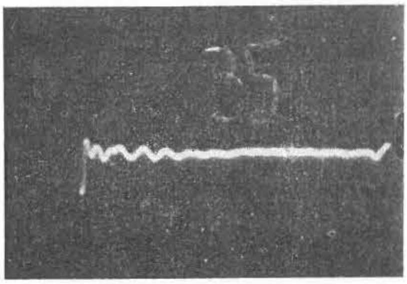

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