In the task of industrial reconstruction after a devastating war which the British scientific instrument industry, in common with other British industries, has now to face and accomplish, its most potent means must be the extension of scientific research to the varied problems of the industry. In this work the co-operative research of the association and the particular research of the individual firms are essential and complementary. The work of the association does not supersede, but emphasises the need for, and assists, the scientific research undertaken by individual firms. In the same way, the pure science research of the universities and kindred institutions is essential and complementary to all re-

search carried out by the research associations or by industrial firms. The universities and their like are the great sources of purely scientific research, and to them we look for that fundamental work which, probably in many cases not of immediate applicability to industry, is bound to be the foundation of future guiding principles. Nowhere is this more fully recognised than in the British Scientific Instrument Research Association. Its work is also largely purely scientific, but to fulfil its purpose of immediate utility to its relevant industries it necessarily cannot always follow through to completion the numerous lines of investigation which arise out of the problems studied.

Microseisms.

By J. J. SHAW.

HOW often we use the term "terra firma"! It is used despite the fact that no square yard of the earth's surface is ever at rest; an unending train of waves, waxing and waning in amplitude, are unceasingly coursing along the earth's crust and to unknown depths. The wave period ranges between 4 and 8 secs.; the amplitude is between $1/50,000$ and $1/2000$ in., but with a wave-length of 8 to 16 miles. The speed of the waves is believed to be about 2 miles per sec. These microseisms have been known to seismologists for twenty years or more, and were originally thought to be air tremors. Later, the rocking of the observatory buildings in the wind was suggested as their origin, or the rocking of the ground due to the motion of trees in the vicinity; but it is now established that these disturbances are pure earth-movements travelling over long distances. With sensitive seismographs, microseisms are easily recorded, but whilst hypotheses have not been lacking, their origin and cause still remain unknown.

Prof. John Milne, in 1898, suggested ("Seismology," p. 285) that the cause may be twofold: (1) air currents and convection currents within the instrument cases; (2) a ground movement produced by rapid changes of barometric load. Before that time, Bertelli and Rossi had noted the connection of microseisms with barometric change.

In America, Burbank observed an increase in amplitude when a barometric load passed from land to sea, or *vice versa*. At the International Seismological Congress held in Manchester in 1911 funds were provided for the investigation of microseisms, and Prof. O. Hecker, of Strasbourg, was deputed to undertake the work.

Daily comparisons were made between the microseisms recorded and the state of the sea at Cape Grisnez, Heligoland, and Borkum, a connection between sea waves and these movements having long been suggested. The war intervened, and the conclusions do not appear to have been published.

In earthquake investigation observers are by NO. 2663, VOL. 106]

this time fairly familiar with the easily recognisable chief phases, viz. "primary" and "secondary" waves, followed by "long waves" which rise to a "maximum"; hence it is comparatively simple to trace any particular phase around the globe, and by this means to determine the respective rates of propagation and to compile seismological tables for future guidance.

Microseisms do not lend themselves so readily to this kind of treatment. Fig. 1 illustrates a section of a record when microseisms are pronounced, and shows how similar one train of waves is to the next, thus defying identification of any particular wave at distant stations.

In May, 1917, the present writer was testing two similar seismographs in different buildings 60 ft. apart. The machines were arranged on the same electrical time circuit, and both oriented in the same azimuth. It was observed how closely similar were the microseisms on both records, showing that the air tremor hypothesis was untenable. A seismograph has two kinds of sensitivity—one to tilt, in which the period of the pendulum plays the more important part; the other to a horizontal thrust, where the ratio of the leverage, operating about the "steady-point," is the chief factor. These seismographs were constructed with the same sensitivity to horizontal thrusts, but, as an experiment, the period of one pendulum was raised until the sensitivity to tilt was four times that of the other. Under these conditions the recorded amplitude of the microseisms was approximately the same, whereas the large waves of an earthquake which were recorded were from three to seven times greater on the machine more sensitive to tilt. This seems to suggest that microseisms are principally a horizontal motion; but against this must be noted that seismographs designed for vertical motion record microseisms quite freely.

The fact that microseisms could be identified on instruments 60 ft. apart pointed to the advisability of attacking these waves on entirely new lines, viz. gradually to extend the distance between the observing stations so long as the identification of

the individual waves remained possible. The use of a "dug-out" in a pit bank was secured, distant two miles from the home station, in a direction 17° west of north, and one of the instruments installed there. Both instruments were arranged in the same azimuth, with the same period, damping, and ratio of magnification. The clocks could be synchronised only by motoring between the two stations with a watch that varied about one-fifth of a second per hour. Comparisons were made

"DUG-OUT." 10.2.20

FIG. 1.—Earthquake and microseisms.

both ways, and the precision was calculated by interpolation. On favourable occasions the clocks were set alike within about one-tenth of a second.

It was at once seen that there would be no difficulty in identifying the waves at stations two miles apart (see Fig. 2). The films were timed by a short

"HOME" 11.3.20

"DUG-OUT."

"HOME" 14.2.20

"DUG-OUT."

FIG. 2.—Comparative traces.

eclipse of the light every minute. In the first attempt the clocks were compared once daily, and the films timed by measuring from an eclipse to the nearest apex in the trace. By this method differences of as much as two seconds were noted, whereas one second was the maximum expected from the known rate of surface wave transmission. It was evident that a higher precision

was necessary. The errors were chiefly traced to a lack of uniformity in the peripheral speeds of the recording drums. In a second series of observations the clocks were compared twice a day, and comparisons of the films limited to the point marked by the eclipse. For the success of this device it was necessary to obtain a record of the wave during the eclipse. This was achieved by cutting a fine slit across the shutter, so that whilst the beginning or end of the eclipse was still clearly defined, the leakage of light through the slit produced a "ghost" during the eclipse.

With the beginning and end of an excursion, and also the time-mark being defined, it remained only to resolve the harmonic motion to obtain the phase of the wave at each station at the instant the shutters closed, and so to deduce the time difference between the two observatories. By the first method there were readings ± 1.13 sec. from the mean. By the second, this was reduced to ± 0.3 sec.; but it is worthy of note that by either method the difference between the two means was only 0.04 sec. for the series.

It was noted that the wave period increased with the amplitude, and the amplitude increases generally with the daily movement of the air. There was, however, one marked exception on March 10, when a very moderate air movement coincided with nearly the maximum amplitude recorded. At this time rough weather was being experienced around the north of Scotland.

The chief objective in these proceedings was a comparison of wave direction with wind direction, and perhaps in its complete failure lies the greatest value of these observations, for it was discovered, it is believed for the first time, that there is practically no change in the wave direction, whatever the meteorological conditions may be. The microseisms always came, more or less, from the north—they always arrived at the "dug-out" first by about 0.8 sec. The small variations in time difference shown in column 2 of the table may or may not indicate a varying azimuth. It is equally probable that they are the result of personal or instrumental error.

To reduce the difficulties and shortcomings in the above experiments, it is proposed—with improved timing facilities and three machines placed at the corners of a 10-mile triangle—to continue this investigation, when it is hoped not only to obtain more precisely the rate of propagation, but also to determine to what extent the azimuth is constant. It would be of value if observers in other countries were to pursue the study of microseisms on this new system in order to determine whether this unidirectional character of the phenomenon is universal,

and, if so, whether the direction is governed by the contour or physical features of the country.

By First Method.

Date, 1920	Difference, Sec.	Wind direction	Daily horl. motion of the wind, Miles	Amplitude μ	Wave period, Sec.
Jan. 31	0.0	S.—W.S.W.	427	5.8	7.3
Feb. 2	0.0	S.W.—S.	587	4.0	7.5
" 6	1.5	S.S.E.	295	2.8	6.7
" 9	1.0	W.S.W.	491	3.2	6.3
" 10	1.0	S.W.	670	9.5	8.0
" 12	0.0	W.N.W.—S.	354	3.6	6.2
" 13	2.0	S.S.W.—W.	528	6.4	6.8
" 15	1.5	S.	423	5.0	6.2
Average	0.87		472	5.0	6.9

By Second Method.

Date, 1920	Difference, Sec.	Wind direction	Daily horl. motion of the wind, Miles	Amplitude μ	Wave period, Sec.
March 4	1.0	W.S.W.—S.	260	4.9	7.5
" 5	1.0	S.	285	1.6	6.7
" 6	0.75	S.	476	4.5	6.0
" 8	1.1	N.W.	407	2.4	6.7
" 9	—	W.	178	—	—
" 10	0.7	S.S.W.	272	7.0	7.0
" 11	1.1	N.W.	257	4.9	6.5
" 12	0.5	W.	541	5.7	6.0
" 13	1.0	S.	377	4.5	6.2
" 18	0.8	W.	500	4.0	6.7
" 19	—	W.	228	2.0	6.0
" 20	—	W.	131	0.8	5.5
" 24	0.8	S.	348	4.0	7.3
" 26	0.7	S.	613	5.3	7.3
" 28	0.8	S.	498	3.2	5.7
Average	0.83		371	3.9	6.5

The Tercentenary of Jean Picard.

By DR. J. L. E. DREYER.

AN article on "Le tricentenaire de l'abbé Picard," by M. E. Doublet, in the *Revue générale des Sciences* (September 15-30), directs attention to the tercentenary of the well-known French astronomer, Jean Picard, who was born on July 21, 1620. Very little is known about Picard's life, so that even the year of his death is uncertain (about 1683). He was a pupil of Gassendi, and took up the study of astronomy at latest in 1645, when he observed the eclipse of the sun on August 21 of that year, and it was as an observer that he was chiefly distinguished. Though he was not the first to apply telescopic sights to astronomical instruments, he was almost certainly not aware that this had many years before been done by William Gascoigne; but Picard was at any rate the first to make use of this invention in an extensive series of observations, when he, in 1669 and 1670, determined the size of the earth. This was done by a triangulation from Sourdon, near Amiens, to Malvoisine, south of Paris, on the plan first proposed and carried out by Snellius about fifty years earlier. Picard measured a base along a level and well-built road from Villejuive to Juvisy, 5663 toises long. It is deserving of special notice that he compared his standard toise with the length of the seconds pendulum, "lest the same should happen to it as had happened to all previous standards"; and that did indeed happen, for his toise is lost. The results of this, the first modern geodetic operation, were published in Picard's "Mesure de la terre" in 1671.

In 1669 Picard presented to the Academy a memoir on the most important astronomical observations which ought to be undertaken. Among these is a new determination of the right ascensions of stars by direct comparison with the sun; this had never been done before without observing an intermediary body (the moon or Venus) which could be seen in the daytime. But it was now possible, as Picard had found in the previous

year, to observe stars in daylight with the telescope attached to his quadrant. Another desirable undertaking was the accurate determination of the position of Tycho Brahe's observatory. This he was able to carry out in 1671, when the Academy sent him to Denmark for that purpose. The results of his observations on the site of Uraniborg were published in 1680 in his "Voyage d'Uranibourg." This expedition became memorable in two ways. First, because Picard, in his account of it, describes certain apparent motions of the Pole-star towards or away from the pole, of which the period was a year, and which, he says, he had noticed for about ten years. From the details given, it is evident that Picard was the first to notice the effect of aberration on the apparent place of a fixed star; and when he adds that these irregularities were in some years smaller than in others, it shows that the effect of nutation was also beginning to be felt. But it was reserved for Bradley both to discover the laws governing these phenomena and to give the correct explanation of them.

The second valuable result of Picard's journey to Denmark was that he made the acquaintance of Römer at Copenhagen, and persuaded him to go to Paris with him. Römer stayed nine years in Paris, and it was there that he in 1675 announced his discovery of the gradual propagation of light. We know from his letters to Huygens that he at once realised that this must produce aberration. Considering that he and Picard lived together at the Paris Observatory, it is rather strange that they did not compare notes and remark how perfectly this agreed with Picard's observations of the Pole-star. But Römer scarcely ever published anything, so it is not impossible that he may have noticed the agreement, and did not care to publish it.

Picard from time to time carried out various geographical operations in France, the results of which are included in his "Ouvrages de Mathe-