say that that opinion no longer prevails, and among the requirements hereafter of a well-appointed establishment will be a properly constructed storm cave.

THE FORCE OF A TORNADO.[1]

By B. F. GROAT, Instructor in Mechanics, School of Mines, University of Minnesota. Dated, Minneapolis, July 24, 1899.

About forty hours after the recent tornado of June 12, at New Richmond, Wis., the writer and Mr. Peter Christianson, also of the University of Minnesota, visited the scene of the disaster.

At Boardman, Wis., about five miles from New Richmond, on the line of the Chicago, St. Paul, and Omaha Railway, we were much interested in two railroad switch targets, the rods of which, apparently owing to the great wind pressure on the surface of the targets, had become bent at an angle which from the train carrying us by we estimated at from 30° to 40° from the vertical. We endeavored to secure these rods from the railroad company in order that we might test the tensile strength of the rods and measure the angle of bending by which we might arrive at the average wind pressure on the vanes, but before Mr. W. A. Scott, General Manager of the railroad could get word to his men, considerable time having been unavoidably lost, the rods had been straightened Mr. Scott, however, very kindly furnished us with the most important dimensions of the targets, from which we have made a calculation that we think may interest the Weather Bureau; at least we believed others would like to know that two rods of the dimensions shown on the accompanying sketch (omitted) had been bent, as we suppose, by the force of the wind.

The exposure of the switch target to the wind is shown by an accompanying sketch (omitted.) A round vertical iron rod, $1\frac{3}{8}$ inch thick, supports vertically a feather-shaped iron plate that is 30 inches long and 13 inches broad.

The following is a brief outline of what we observed and our calculation: The two targets were apparently struck nearly normal to their surfaces by the wind. We had no opportunity to make a survey of the ground, although as we passed by we saw no evidence that the targets had been struck by flying débris of any consequence, but, of course, there is a chance that this may have been the case. As we could not learn the exact value of the angle of bend, we did not think the data sufficient to warrant a test of the tensile strength of the rods, but merely assumed a probable value, and from that and the dimensions of the target, calculated the average pressure per square foot of surface of the vane necessary to bring the bending moment of the rod to the point of straining.

The center of gravity of the surface exposed to the wind is about 36 inches along the central line of the rod above the bend. The area of the target, including that portion of rod above bend, is about 343 square inches. The rod at bend is $1\frac{3}{8}$ inches in diameter.

Assuming that the rod has a tensile strength of 30,000 pounds per square inch at elastic limit, which serves approximately either for wrought iron or soft steel, it is easy to show by the ordinary rules of mechanics, that the average pressure must have been at least 90 pounds per square foot of area normal to the wind, provided our assumptions are correct. If we use for the relation between pressure and velocity the formula $P = 0.005\ V^2$, we arrive at 134 miles per hour. Of course, to bend the rods to the angle mentioned would require considerable more pressure, but probably not enough to render it improbable that the rods were bent by the unaided force of the wind, especially when it is remembered that the tensile strength may be less than assumed. See line 16 from top of page 54, "Report of Board of Engineer Officers as to the maximum span practicable for suspension bridges," published by the War Department for a similar calculation in connection with the tornado that crossed the Champ de Mars.

[1] In submitting the accompanying article, Mr. B. F. Groat desires that attention be called to the fact that there is a possibility that the switch targets mentioned by him were struck by some heavy piece of flying material and not bent by the force of the wind only. On this point, he says he could not secure absolute evidence, but, from all that could be learned, he was led to believe that the targets were bent by the unaided force of the wind. Mr. W. A. Scott, General Manager of the Chicago, St. Paul, Minneapolis, and Omaha Railway made every endeavor to secure all desired information, even ordering the targets and rods taken out and shipped to him by express, for which courtesy Mr. Groat desires to make full acknowledgement.—ED.

SUDDEN OSCILLATIONS IN LAKE LEVEL—PRESSURE WAVES.

By ALFRED J. HENRY, Chief of Division.

[Extract from Lake Chart, September, 1899.]

A so-called tidal wave swept southwestward over Chequamegon Bay on the morning of July 22, 1899. The water of the bay rose suddenly about 3 feet above the normal stage, flooding a number of docks in Ashland, Wis., at the head of the bay, and causing several mills to shut down temporarily. At 11:30 a. m., the water began to recede, and by 3 p. m. it was slightly below normal. A second rise occurred about 4 p. m., and minor oscillations were noticed until the waters assumed their normal level. The wind was from the south and the weather fair.

Sudden waves and swells in tranquil weather have been noted on the Great Lakes, and commented upon from the earliest historic times. These sudden oscillations have never been, so far as known, of sufficient amplitude to seriously injure a vessel on the open lake. They may easily, however, be the cause of considerable damage in narrow channels, and especially in harbors where the shore lines converge to a point, as in the case of Ashland, thereby greatly increasing the size and destructiveness of the wave.

In April, 1893, a somewhat similar wave swept over the southern portion of Lake Michigan, causing a rise of the water in the harbors of about 4 feet.[1] Considerable damage was done to vessels anchored in the Chicago River and ports along the southeastern shore of Lake Michigan. The question was then asked, can these waves or *seiches*, as they are sometimes called, be predicted a few hours in advance of their coming?

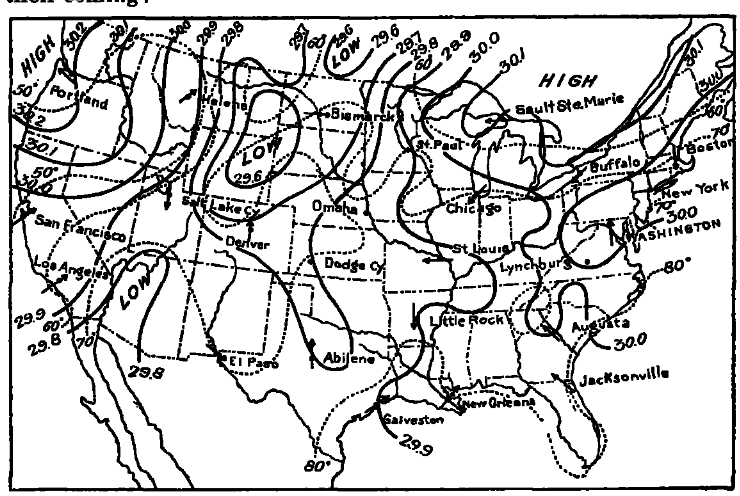

Fig. 4.—Pressure, temperature, and wind direction, 8 a. m. July 22, 1899 (75th meridian time).

The wave in Chequamegon Bay occurred at a time when the local weather conditions gave no sign of unusual disturbance. The daily weather map, however, shows that a storm whose influence extended over the region in question, was passing eastward north of the international boundary line. [See Fig. 4.] Light rain had fallen at Duluth and Port Arthur, but it is not known whether or not rain fell at Ashland.

The occurrence of sudden changes in the levels of lakes has been

[1] See Marine Record, April 13, 1893, American Meteorological Journal, October, 1893.

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