was signed. Bay Shore had been equipped, but never operated. Halifax and Chatham were supplied at this time with equipment for pilot-balloon work, and five complete outfits for France were on the wharf awaiting transportation.

In addition to the Air Stations above named, Brunswick, Ga., and Hampton Roads, Va., have since been put on an operating basis. Rockaway Beach, Long Island, N. Y., has also been equipped. Several of our stations are now regularly cooperating with the Weather Bureau, sending in daily reports of conditions in the upper air and receiving regular forecasts. At nearly all the patrol and flying stations, commanding and flight officers are kept informed constantly of the force and direction of the wind at flying levels and of the weather to be expected during practice hours.[1]

For more than a year the Observatory has been working to secure a suitable recording instrument for measuring meteorological conditions in the upper air while carried by a seaplane in flight. Two forms of instruments for this purpose are now nearing completion. Their perfection will complete the instrumental outfit for Naval Aerography.

[1] See map p. 209 for location of the naval aerological stations.

METEOROLOGY IN THE NAVAL AVIATION SERVICE OVERSEAS.

RUY H. FINCH, U. S. N. R. F.

[Dated: Weather Bureau, Washington, Feb. 14, 1919.]

Aside from bombing a few ports held by the Central Powers and some convoying of ships, the work of naval aviation was primarily hunting submarines. Hence forecasts and data were mainly for use over the ocean.

Forecasting for the coastal waters of northwestern Europe presented many difficulties, especially to those who had been accustomed to having a broad expanse of land to the west from which reports are received showing the more or less regular progress of HIGHS and LOWS. There, too, one had to deal with a series of LOWS with only occasionally an intervening traveling HIGH. The HIGHS that most commonly affect the western coast of Europe—oceanic conditions—are the slowly shifting, sometimes stationary ones either of continental origin or from the Azores region. The first intimation of the approach of a storm to northwestern Europe in the absence of wireless reports from the Atlantic is from the effects due to the storm itself—the formation of cirrus and other characteristic clouds, the falling of the barometer, and the backing of the wind at the westernmost stations. This latter often seems to anticipate a fall of the barometer, but it is still a mooted question whether the backing of the wind precedes or accompanies the change from stationary, or rising, to falling barometer.

At many of the American stations it was impossible to get the British forecast, or any reports, in time to help in making the morning forecast; and one had to be guided by local conditions and by old reports. The backing of the wind and fall of the barometer would herald the approach of a storm; but, of course, only a short time before the onset. Clouds, however, gave more advance information of the coming LOW. Along the western coast of France and over the British Isles the wind circulation nearly approaches the ideal circulation found in well-defined storms over the ocean. Most of the meteorological huts were stationed along or near the coast, usually near the landing places of the seaplanes, and were excellently situated for cloud observations. By noting the appearance and direction of clouds of the cirrus level, and the time interval before the developing of alto-types, one could get a good idea of the intensity and distance away of coming storms. By noting departures from expected wind direction and cloud movements, and assigning a reason for such departures, one could often locate secondary depressions, even when they were passing to the south of the observer. When low clouds prevented good cloud observations one had to be guided by the wind direction and the barometer. In many cases elaborate cloud observations were unnecessary, for short-range forecasts—6, 12, and 24 hours—were all that were desired.

Synoptic charts were drawn, and, though usually too late to be used in making morning forecasts, they gave a good check on the interpretation from local conditions, and aided one in studying the causes and effects of weather happenings. In cases where synoptic charts were available in making forecasts they were used only in conjunction with local conditions. Land-and-sea-breeze conditions occasionally afforded easy forecasting of wind velocity and direction.[1]

Forecasts included wind velocity and direction from the surface up to 2,000 or 3,000 feet, weather (rain or fair), height of clouds if low, and visibility. At stations where dirigibles were used forecasts had to be more definite and a closer watch kept of the weather than at seaplane stations.

Visibility is of prime importance in hunting submarines from aeroplanes. A haze that would permit of fair discernment of large objects would completely obscure a periscope or a submarine slightly submerged. The forecast of visibility was for the distance in miles at which selected objects could be clearly seen. Colored glasses for observing through haze were used with some success. By noting the causes of poor visibility, and by correlating visibility at sea with the visibility and general conditions near the meterological hut, one could make good forecasts of the visibility seaward. Although a qualified observer, it was mainly for visibility correlations that the writer went up on a patrol as observer.

The British forecasts always included the gradient velocity, which was assumed to obtain at 1,500 feet. The British Admiralty, however, were inclined to take 2,000 feet as the average level at which the gradient velocity is reached. The current gradient velocity was obtained from the weather map by means of transparent scales similar to those drawn in figure 1. They were calculated for the latitude of the British Isles for use on the daily weather reports (scale 1/20,000,000) with isobars drawn for every 5 millibars. Several radii of curvature for both cyclones and anticyclones are usually given, and one or two trials will usually show the curve nearest the required isobar. Then, by noticing where the next isobar crosses the scale, the wind velocity is read off. From theoretical considerations of the decrease of density and the pressure gradient with increase of elevation tables have been computed giving velocities for all elevations up to 30,000 feet corresponding to gradient velocities at the surface. They were but little used and are of doubtful accuracy.

[1] See discussion of forecasting in western Norway: MONTHLY WEATHER REVIEW Feb., 1919, 47: 90-95

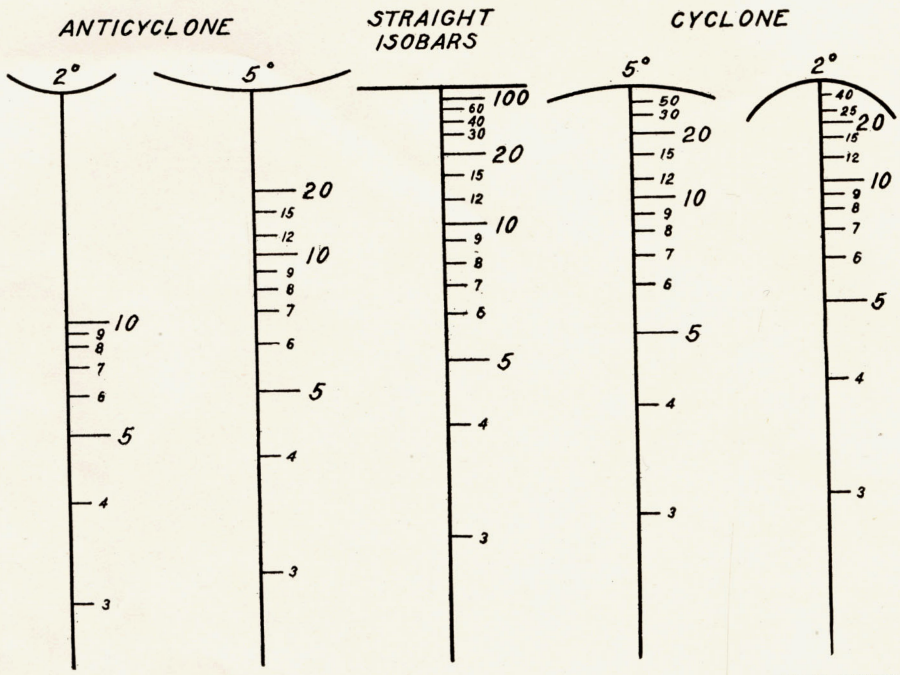

FIG. 1.—Gradient velocity scales, for use on British daily weather report charts (scale 1/20,000,000). Velocities in meters per second.

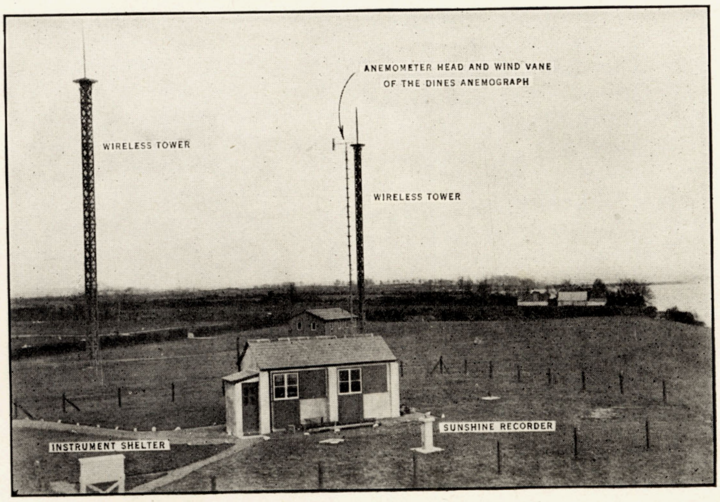

FIG. 2.—Meteorological hut, U. S. Naval Air Station at Wexford, Ireland.

Wind velocity and direction aloft were obtained by means of pilot balloons, and all stations were supplied with equipment for making pilot-balloon ascents. The ballons were inflated to give a rise of 400 or 500 feet per minute, according to the size of balloon used. This rate of rise facilitated rapid calculation; and by the single-theodolite method, with the theodolite near the office, two men could take the data, make the horizontal projection of the balloon path, and within one minute from the time the balloon was lost, complete the tabulation of the wind velocity and direction for all levels reached. A check on the rate of rise was sometimes made by the two-theodolite method. It showed that a balloon with the 500-foot rate varies from 425 to 600 feet per minute, though usually it is not very far from 500 feet. Such a departure from the assumed rate would cause a large percentage of error, but for velocities most suitable for flying it would mean an error of only a few miles an hour. In making night ascents a small candle lantern was tied to the balloon.[1]

Data from the pilot-balloon ascents as well as from surface instruments were used in plotting dead-reckoning courses for seaplane patrol. The wind direction was given in degrees to facilitate computing the drift angle, as most patrols consisted of many courses. Surface-wind data were obtained from the Dines anemograph, which gives instantaneous wind direction and velocity. In case the outlook was unfavorable for a dawn patrol upon the advice of the station meteorological officer the planes were not taken out of the hangars; and if dangerous winds were expected when planes were out it was the duty of the meteorological officer to see that they were recalled.

The type of meteorological hut used in British and American air stations is shown in the accompanying photograph (fig. 2).

[1] See pp. 221, above.

BLUE HILL METHODS OF "PILOT BALLOONING."[1]

By Ivor Mall, Ensign, U. S. N. R. F.

[Dated: Blue Hill Observatory, Readville, Mass., March, 1919.]

Pilot balloons are used to determine wind velocity and direction at various altitudes. To accomplish this, the balloon is released and its successive positions at intervals of one minute are observed through a theodolite. The vertical, or altitude, angle, and the azimuth, or horizontal, angle are noted at each of these minute intervals. From these data, and an assumed constant rate of ascent, the velocities and directions at different levels are calculated.

The solution of the data makes use of simple geometric and trigonometric principles. In order to make the operation more vivid, it is well to concentrate the attention on the procedure and try to visualize what happens when the balloon is released, and then to determine the value of the recorded data.

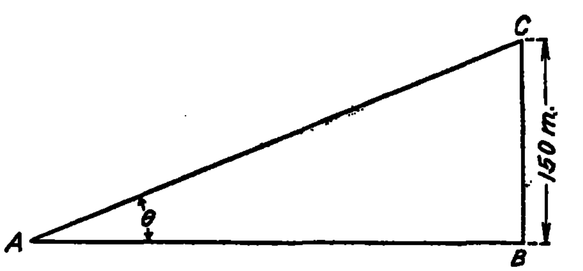

Fig. 1.—A represents the point at which we are standing and what we shall call the base; C is the position of the balloon; B is a point projected vertically below C; θ is the recorded vertical angle.

Let us stand with our backs to the wind and with a properly inflated balloon at hand. We will assume that the balloon when released will have a constant rate of ascent (150 m./min.). We release the balloon and it starts to rise and is carried out and away from us by the force of the wind. At the end of one minute we observe its position with the theodolite. According to our assumption its height is 150 meters. We record the vertical angle. This is represented in figure 1. AB represents the horizontal distance with respect to the earth that the balloon has traveled in one minute. If we divide the distance AB by 60, we obtain the wind velocity in meters per second (m./s.).

[1] Published by permission of the Secretary of the Navy.

To find AB we have the following trigonometric relation:

$$BC \cot \theta = AB.$$

With AB determined we convert it into terms of velocity as explained above.

The above description shows what has happened in the vertical plane. If the wind direction were constant, this reasoning would be sufficient, but as this is not true another condition is introduced the explanation of which follows.

Let us go back to the point where we released the balloon. We observe its movement at minute intervals as it moves away. After a few minutes we notice that the balloon is being deflected to our right. This would lead us to the conclusion that the wind at the higher levels is from our left rear. In other words, the wind direction is changing as we go aloft. This variation is measured by noting the change of the horizontal angle, or azimuth. A movement takes place laterally with respect to the horizontal plane, which is represented in figure 2. The line AO represents the true balloon travel, hence its velocity. As the balloon has been blown from A to O, it

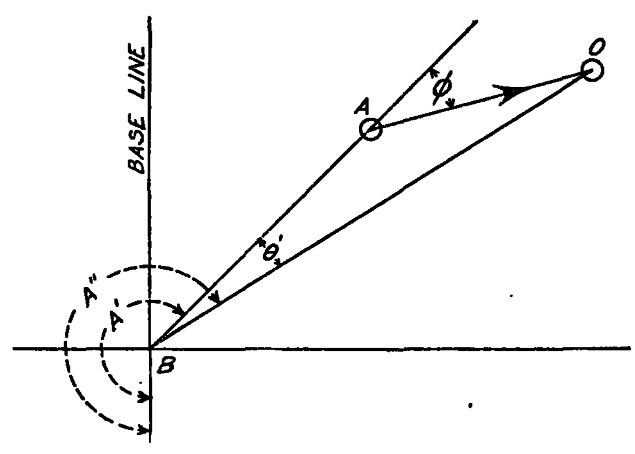

Fig. 2.—B is the base; A and O are successive positions of the balloon at any interval; A'=azimuth of position A; A''=azimuth of position O; θ'=difference in azimuth; ϕ=angle between line of sight of nearest position of balloon and the line of travel of the balloon.