TECHNICAL NOTES

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No. 341

CALIBRATION AND LAG OF A FRIEZ TYPE CUP ANEMOMETER

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Summary

Tests on a Friez type cup anemometer have been made in the Variable Density Wind Tunnel of the Langley Memorial Aeronautical Laboratory to calibrate the instrument and to determine its suitability for velocity measurements of wind gusts. The instrument was calibrated against a Pitot-static tube placed directly above the anemometer at air densities corresponding to sea level, and to an altitude of approximately 6000 feet. Air-speed acceleration tests were made to determine the lag in the instrument reading. The calibration results indicate that there should be an altitude correction. It is concluded that the cup anemometer is too sluggish for velocity measurements of wind gusts.

Introduction

One of the most important items under discussion by the Subcommittee on Meteorological Problems at a meeting early in 1929, was the study of the structure of the atmosphere and the measurement of gustiness. At this time consideration was given to the question of instrument requirements, and it was the consensus of opinion of the representatives of the Weather Bureau and the Bureau of Aeronautics that any instrument used should be of rugged construction and simple in operation. This is apparent, of course, in view of the fact that the instrument may be subjected to all kinds of weather conditions and must make continuous measurements over long periods of time. Aside from these requirements any instrument considered must be tested for its ability to measure rapid changes in velocity; that is, its inertia reactions must be determined. A Friez type cup anemometer had been loaned to the Bureau of Aeronautics by Julien P. Friez and Sons, and since the instrument seemed to meet the requirements of ruggedness and simplicity, it was proposed for use in the preliminary studies. The National Advisory Committee for Aeronautics was requested to make a calibration and lag study of the instrument.

The investigation was made in the Variable Density Wind Tunnel by comparing the anemometer air-speed indications with the air speed as measured by a Pitot-static tube. The purpose has been twofold, namely, to calibrate the instrument against a Pitot-static tube, and to determine its lag characteristics. Calibrations were made at two air densities (approximately 1, and 2/3 atmospheres), in order to determine the effect of change in altitude. The lag characteristics were determined by a direct comparison of anemometer and Pitot-static tube indications during accelerating air flow.

Apparatus and Tests

The cup anemometer tested in this investigation is a three-cup type as shown in Figure 1. The cups, which rotate about a vertical axis, drive an electric generator housed in the body of the anemometer. The e.m.f. generated is indicated by a galvanometer provided with a scale to read in m.p.h. In these tests a photo-recording galvanometer also was used, and both instruments were connected to the generator leads through a double-throw switch so that either instrument could be quickly connected to the generator. The Pitot-static tube used to measure the true air speed was connected to a photo-recording pressure cell (Reference 1). The deflections of both instruments, together with timing marks at $\frac{1}{2}$-second intervals, were recorded on a photographic film. The anemometer was mounted in the center of the air stream and rigidly guyed. The Pitot-ststic tube was mounted directly above the anemometer cups at a distance of 12 inches. The leads and tubes from these instruments were brought outside the tunnel through the regular equipment and connected to the recording and indicating instruments.

The anemometer was calibrated for two attitudes, one with the axis vertical and the other with the axis inclined forward 30 degrees. The air speed was varied from 10 to 45 m.p.h. in six steps, and at each step the photo-recording instruments recorded the Pitot-static tube and anemometer indications.

The pressure difference between a pressure orifice in the return passage of the tunnel and the space surrounding the throat, and the indicated speed (anemometer indicator) were also noted.

Four acceleration runs and two deceleration runs were made during which both the Pitot-static tube and anemometer indications were recorded continuously by the photo-recording instrument.

Additional tests were made later, primarily to determine the effect of altitude, and were conducted without the photo-recording instruments. Calibration tests were made at air pressures of approximately 1, and 2/3 atmospheres, and readings of anemometer indicator, static pressure, and r.p.m. of the tunnel propeller were taken. The latter was taken in order to determine the true air speed at the slower velocities by extrapolation from a curve of air speed versus r.p.m., since the static pressure reading could not be relied upon at slow air speeds.

Results

The results are presented as calibration curves (Fig. 2), lag curves (Figs. 5 to 10), and friction data (Table I). The calibration curves are obtained by plotting the true air speed, as measured by the Pitot-static tube, against the speed indicated by the anemometer. The lag was determined by comparing curves of air speed versus time in seconds from the Pitot-static tube and from the anemometer.

Discussion

Because of the proximity of the Pitot-static tube to the rotating cups of the anemometer, it was thought that the interference of the anemometer upon the air flow about the Pitot might be appreciable. Hence, to determine the amount of this interference the velocity of the air stream was calculated from the static pressure obtained by means of a static-pressure orifice, located in the return passage of the tunnel and calibrated against a Pitot-static tube placed in the center of the air stream, the anemometer being removed. This velocity was compared with that calculated from the Pitot-static tube with the anemometer in place, and the results indicated that there was no appreciable interference between the anemometer and the Pitot-static tube. Figure 2 indicates two factors which affected the instrument calibration, namely, the attitude of the anemometer with respect to the air stream, and the density of the air. With the axis inclined forward 30 degrees the indicated velocity was approximately 6 per cent higher than it was with the axis vertical. At the reduced pressure, the indicated velocity was approximately 6 per cent lower than it was at atmospheric pressure, indicating that an altitude factor should be applied to the latter calibration. Another factor which may have affected the calibration is that the instrument was calibrated in an air stream having a marked pressure gradient in the direction of the air flow.

As previously stated, the lag studies were made by means of continuous, simultaneous records of deflections of the anemometer galvanometer and the Pitot-static tube pressure cell. A copy of one of these photographic records is shown in Figure 3. The higher frequency pulsations in the anemometer record are due to the natural period of the recording galvanometer. The anemometer is checked against the Pitot-static tube to determine the lag, presupposing that there is no lag in the latter. To verify this supposition the air speed was held constant at full value and the deflection of the Pitot-static tube pressure cell was recorded while an obstruction was suddenly placed in front of the tube, then after about five seconds suddenly removed. This photographic record, shown in Figure 4, indicates that the lag in the Pitot-static tube and the recording arrangement was negligible. Figures 5 to 10 present the lag study data in graphic form and show quite clearly the magnitude of the lag in the instrument reading. It will be noted that the lag is appreciable for velocity fluctuations greater than $1\frac{1}{2}$ m.p.h. per second. To further study the instrument lag the time required for the anemometer rotor to reach a constant speed (starting from rest) was measured. This approximate measure of lag was made at air pressures of about 1, and 2/3 atmospheres, in order to determine the effect of change in altitude. At 1 atmosphere the time was about 2.4 seconds, and at 2/3 atmosphere it was about 3.0 seconds, indicating a slightly larger lag at higher altitudes.

Some data concerning the effect of friction are given in the following table:

TABLE I

	1 atmosphere	2/3 atmosphere
Starting air speeds	4.5 m.p.h.	-
" " "	5.2 "	6.6 m.p.h.
Running " "	4.0 "	4.6 "

The starting air speed is defined as the minimum air speed at which the rotor will start from rest. The running air speed is defined as the minimum air speed at which the rotor will continue in motion after being once started. By changing the position of the cups about the vertical axis of the anemometer, it was found that the starting air speed varied as shown by the table.

Unpublished data on wind velocities obtained by the flight research section of the Langley Memorial Aeronautical Laboratory reveal that wind accelerations of 64 m.p.h. per second are sometimes reached and accelerations of 7.5 m.p.h. per second are common. Figure 6 shows that for accelerations of approximately 9 m.p.h. per second the anemometer experiences a lag of about 1/2 second. In the light of these data it is concluded that the cup anemometer is too sluggish for velocity measurements of wind gusts.

Conclusions

1. The calibration results indicate that there should be an altitude correction.

2. The cup anemometer, because of its large inertia, is too sluggish for velocity measurements of wind gusts having accelerations greater than 2 m.p.h. per second.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 17, 1930.

Reference

1. Norton, F. H. and Brown, W. G. : The Pressure Distribution Over the Horizontal Tail Surfaces of an Airplane - III. N.A.C.A. Technical Report No. 148, 1922.

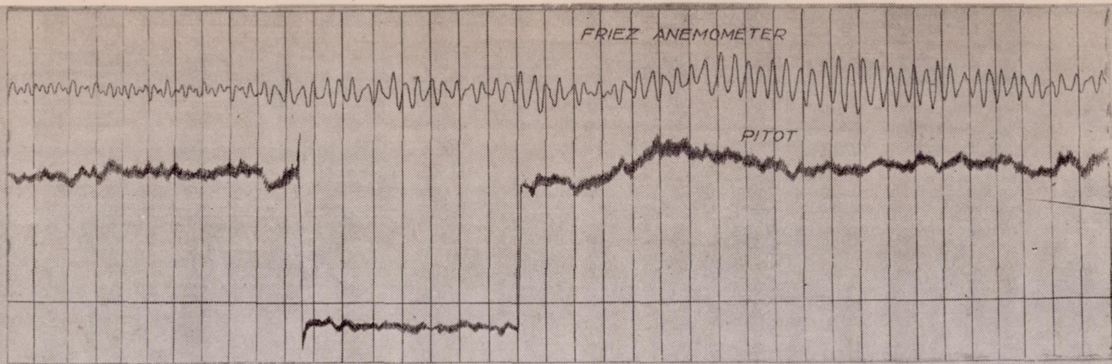

Fig.4 Copy of photographic record of airspeed indications as an obstruction is suddenly placed in front of Pitot and then suddenly removed. (Timing lines are at 1/2 second intervals).

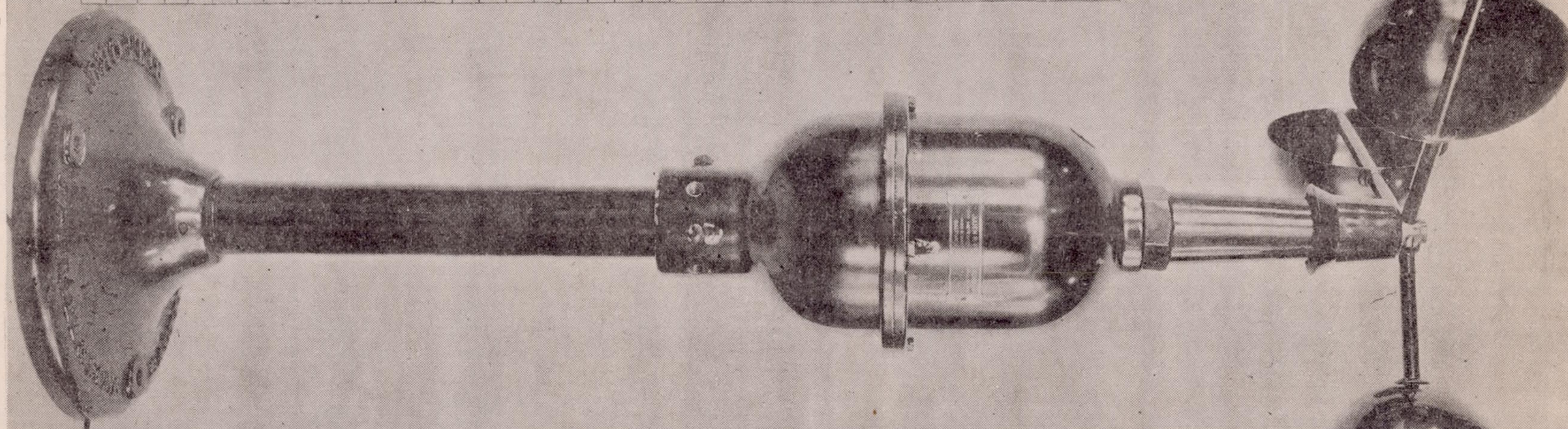

Fig.1 Friez type cup anemometer.

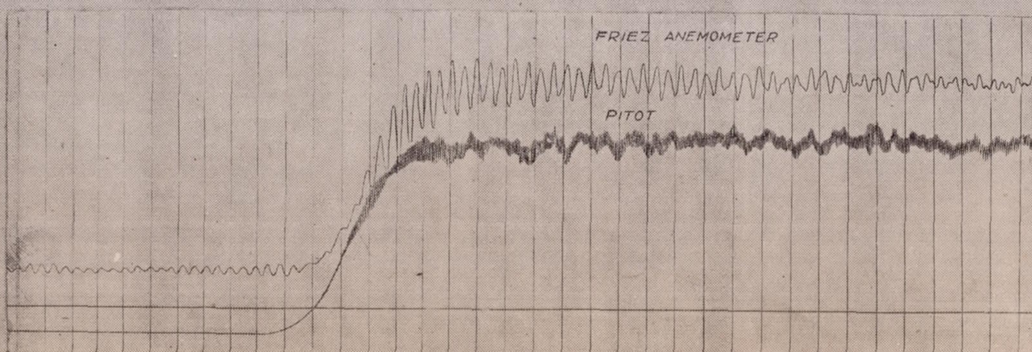

Fig.3 Copy of photographic record of air-speed indications during an accelerating air flow. (Timing lines are at 1/2 second intervals).

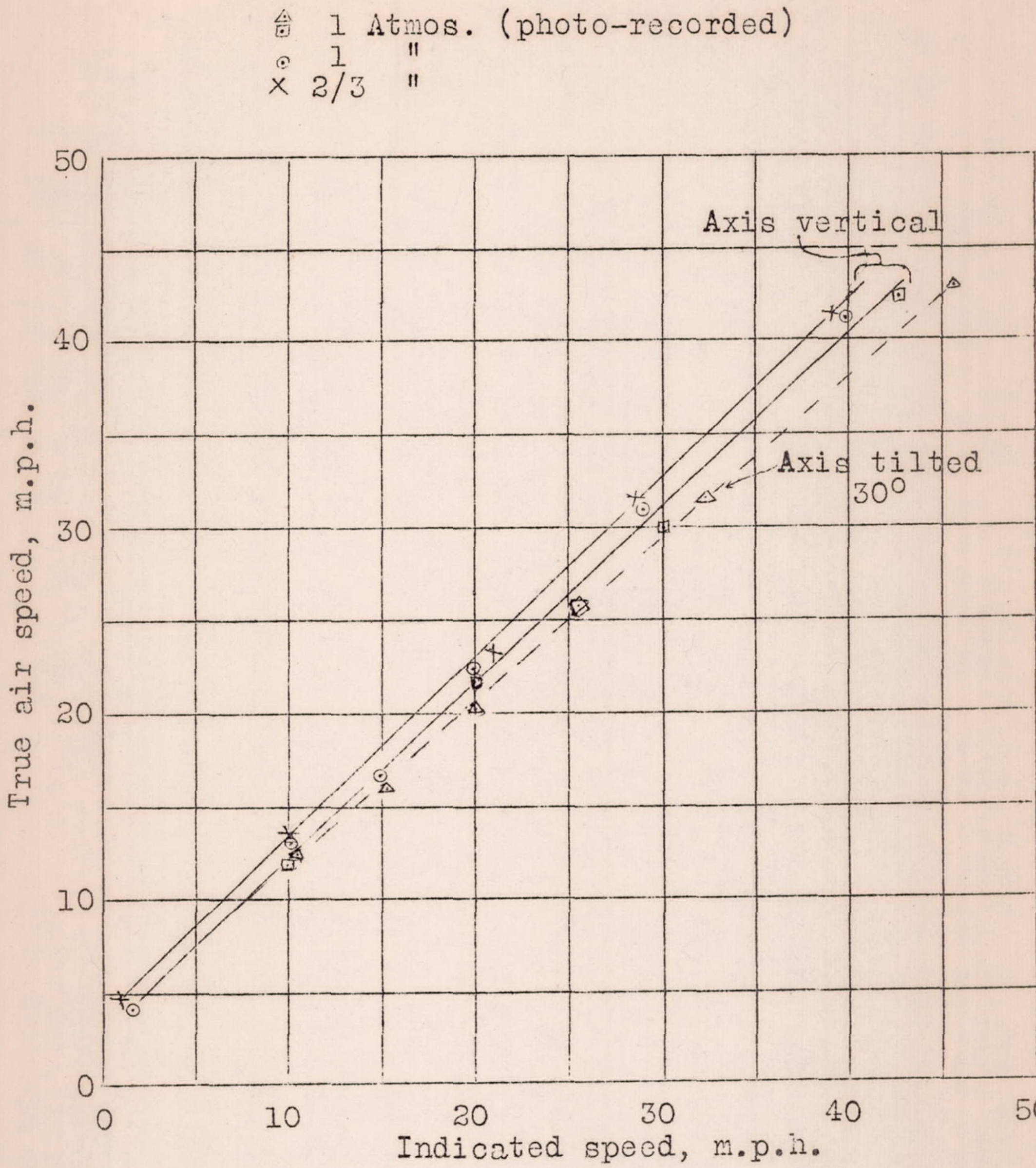

Fig.2 Calibration curves of Friez type cup anemometer.

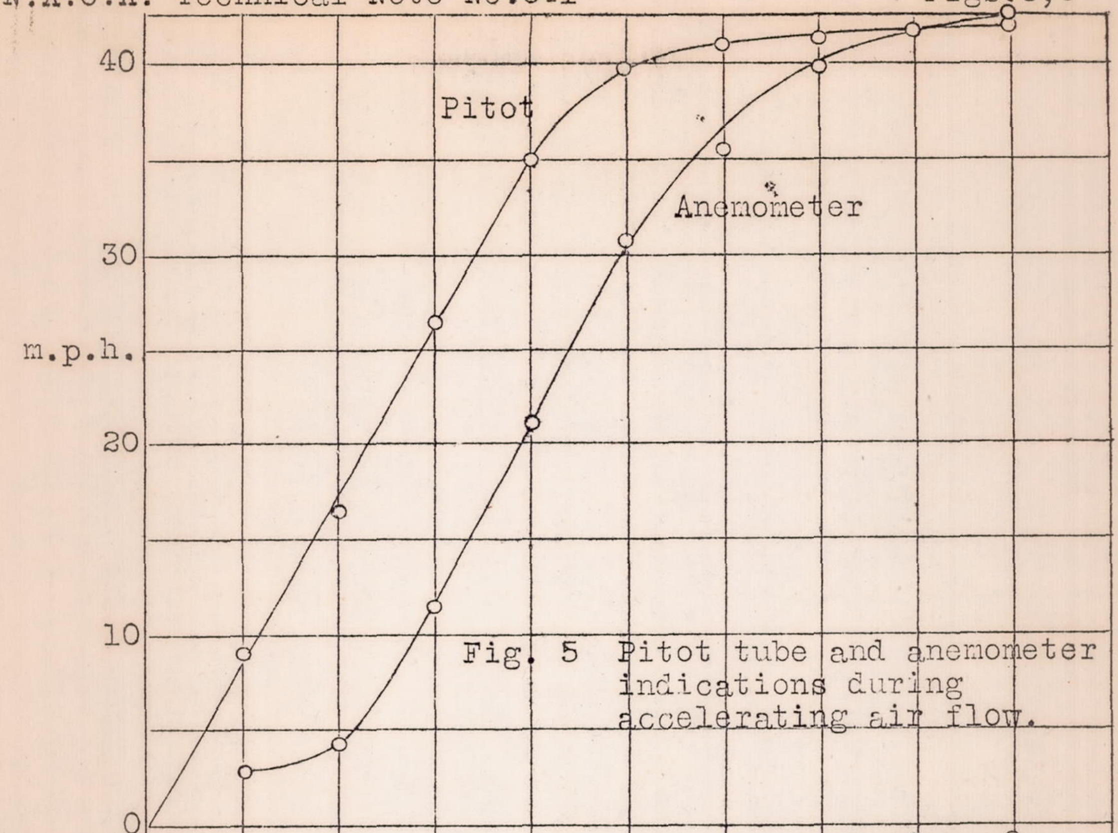

Fig. 5 Pitot tube and anemometer indications during accelerating air flow.

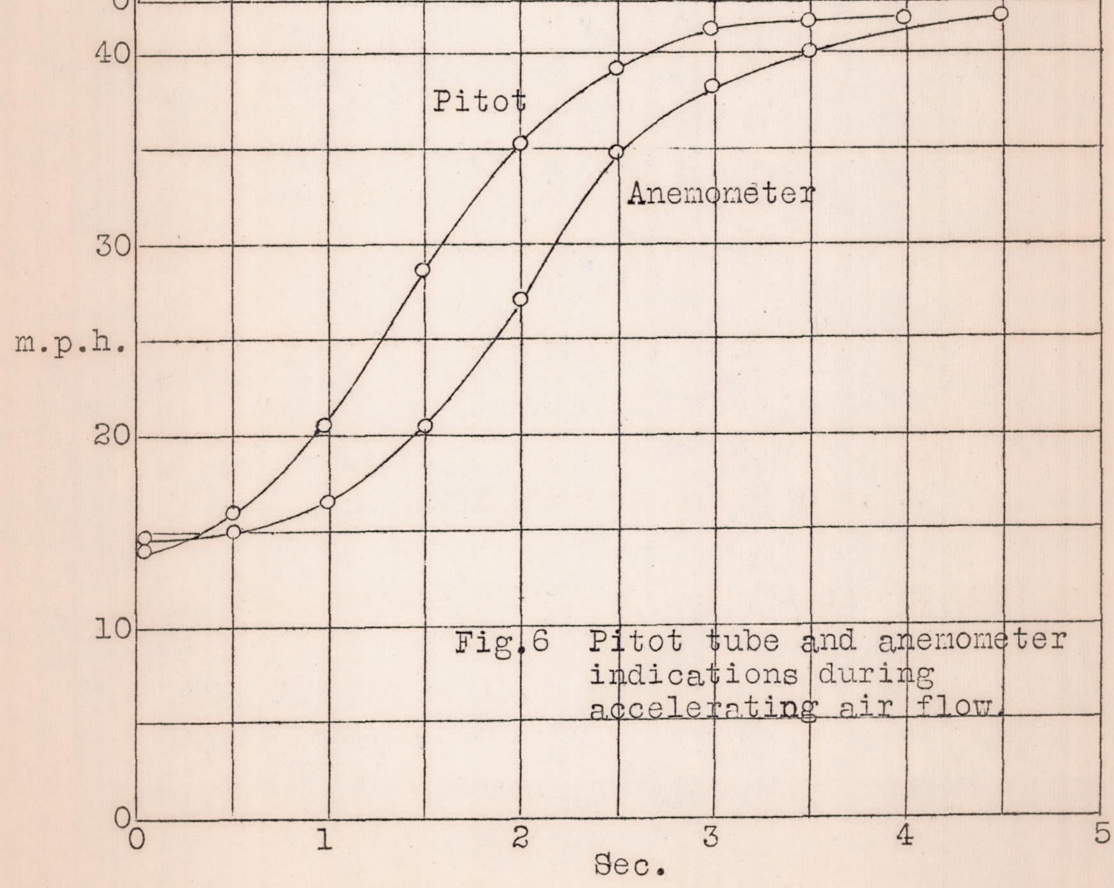

Fig.6 Pitot tube and anemometer indications during accelerating air flow.

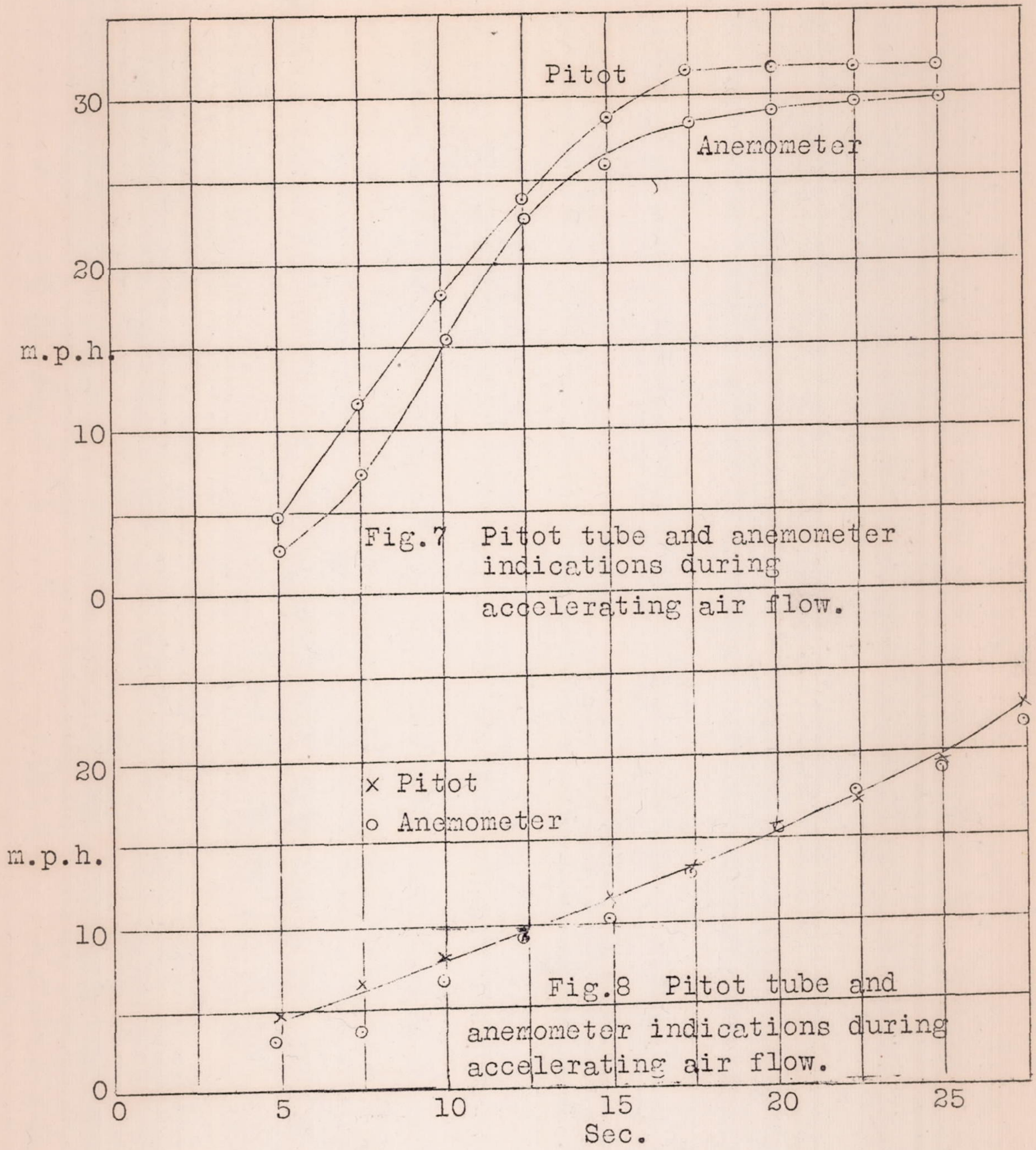

Fig.7 Pitot tube and anemometer indications during accelerating air flow.

Fig.8 Pitot tube and anemometer indications during accelerating air flow.

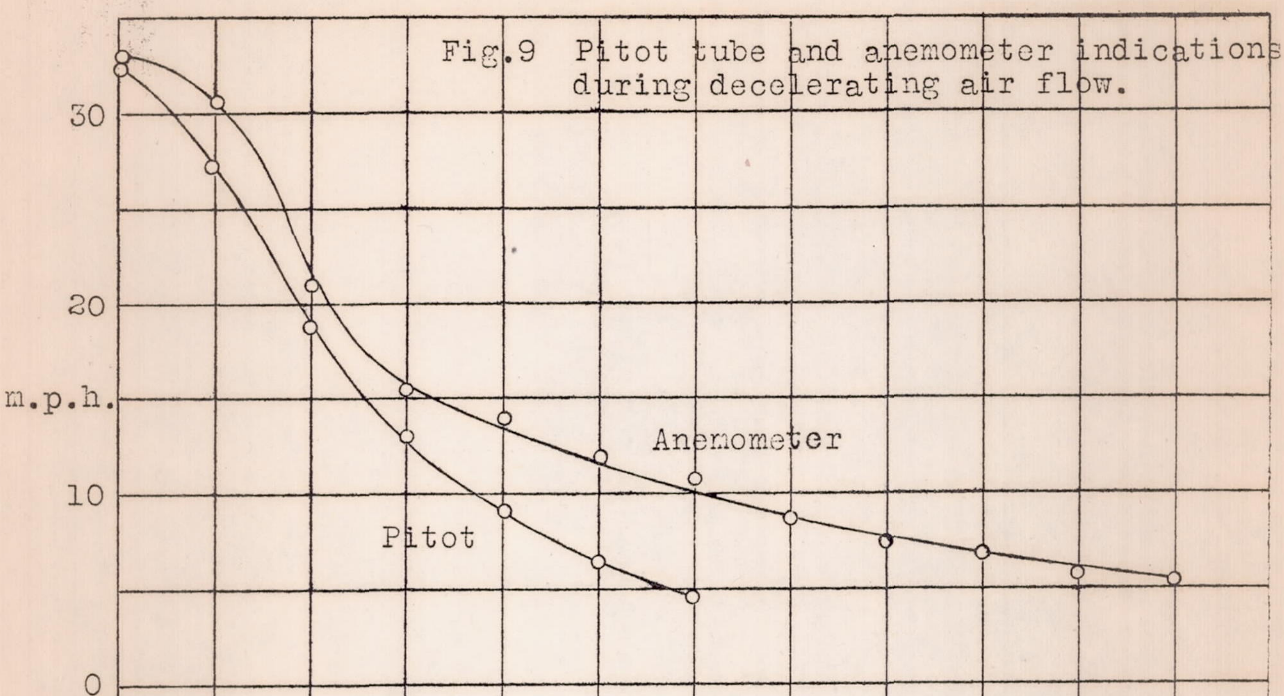

Fig.9 Pitot tube and anemometer indications during decelerating air flow.

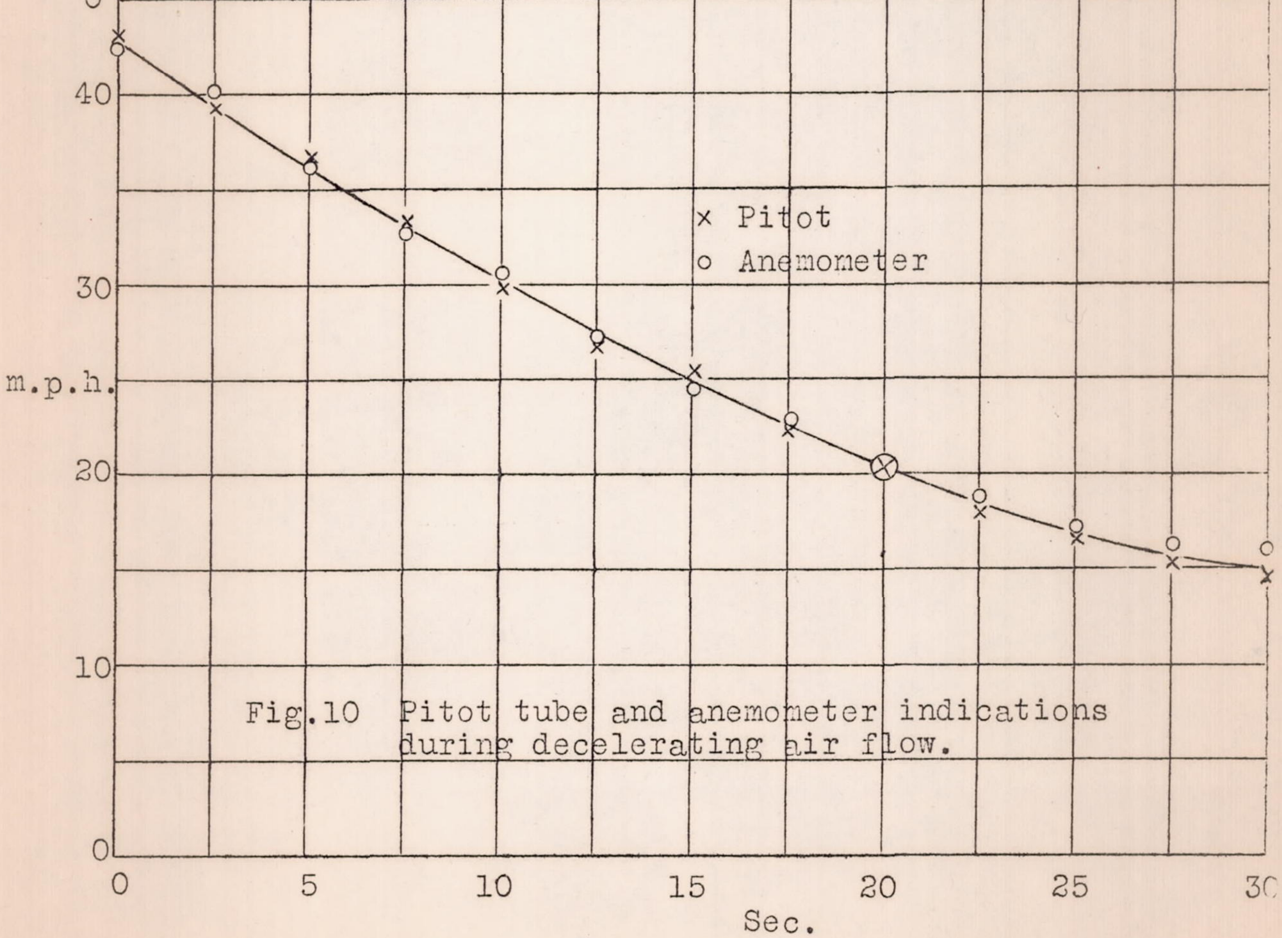

Fig.10 Pitot tube and anemometer indications during decelerating air flow.