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PRELIMINARY INVESTIGATION OF PILOT SCANNING TECHNIQUES OF DIAL POINTING INSTRUMENTS

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SUMMARY

A preliminary analysis has been made of two pilots' methods of looking at instruments with needle pointers in a fixed-base helicopter simulation. A total of 45 runs were analyzed for each pilot. The data indicated that two apparently different techniques were being used; one looking at the needle point, the other looking at a fixed spot on the instrument and reading the needle direction parafoveally. In the analysis, the latter technique was found to be somewhat faster with both pilots accomplishing the flying task. Further tests are recommended to determine if one technique is superior to the other and also to find methods of teaching the superior techniques to pilots.

INTRODUCTION

In the past, analysis of pilot scan patterns has been primarily directed at determining which instrument the pilots look at in an instrument array (ref. 1). With the more complicated instruments, such as a flight director, analysis was extended to determine which of the information areas of the display the pilot looked at. None of the studies, however, have addressed the question of what the pilot looks at specifically when he is looking at an instrument with a dial. A typical instrument is about 6.7 centimeters wide while the foveal field of view covers an area of about 2.5 centimeters in diameter on an instrument panel. Does the pilot use foveal or parafoveal vision to determine where the dial is pointing? Previous studies have shown that subjects were able to detect dial pointing direction correctly 50 percent of the time out to 60 degrees peripherally (ref. 2). However, it is not known if, or to what degree, this peripheral vision capability is used by pilots in an actual or simulator cockpit environment. Lookpoint data from two pilots were taken from a simulator display comparison study conducted at the Langley Research Center and analyzed with the above questions in mind.

SYMBOLS

p percentage of dwell time in a given interval along a specific axis

n an axis along the needle point

y an axis normal to n

METHOD

Simulator

The pilot lookpoint data were taken from tests designed to evaluate advanced instrument landing displays for helicopter landing approaches. The advanced displays were presented on a color cathode ray tube display located in the center of the instrument panel (fig. 1). Four other conventional instruments, airspeed indicator, altimeter, rate of climb, and turn and bank were located around the advanced display. The pilot's task was to intercept the localizer at a 45 degree track and follow a 6 degree glide slope to a hover at 8 meters altitude and maintain a hover for 45 seconds. The simulator cab was a multi-purpose cockpit/motion base (ref. 3) arranged with conventional collective, cyclic, and rudder pedal controls. The equations of motion were solved digitally 32 times a second and were representative of a marginally stable helicopter (ref. 3) with no stability augmentation. Each pilot's data were analyzed for 45 fixed base data runs covering three CRT displays and three wind conditons repeated five times.

Pilot Lookpoint Data

The pilots' left eye was tracked with Langley Research Center's oculometer (ref 1) to determine their lookpoint on the instrument panel. The oculometer consists of an optical head (fig. 1), a minicomputer, and associated television interface and processing equipment (fig. 2). The optical head generates a beam of infrared light that is directed at one of the pilot's eyes by a moving mirror assembly controlled by the computer. The infrared light is reflected from the corneal surface giving a point reflection and from the retina which backlights the pupil (fig. 3). These reflections are returned to the optic head and focused on a television vidicon tube. The resulting television picture of the eye is analyzed by a minicomputer, which by using the relative positions of the cornea and retina reflections calculates the pilot's lookpoint on the instrument panel. The oculometer system is calibrated for each pilot by the pilot looking at known points on the instrument panel. The oculometer minicomputer takes these data and automatically adjusts a set of linearization coefficients to make its output of lookpoint match as closely as possible the ideal points. The overall accuracy of the oculometer using this linearization technique has been measured by the manufacturer to be better than 13 mm at the instrument panel when the lookpoint is within 20 degrees of the EO head. In addition to the linearization procedure, the pilots were asked to scan around the circumference of each instrument on the panel to provide accurate instrument locations for use in the post-processing of the oculometer data. It is estimated that this technique reduces the error to less than 6 mm.

Pilots

Data will be presented for two pilots who participated in these tests. The first one (Pilot A) was a former military pilot with considerable experience in the simulator. The other pilot (Pilot B) was a test pilot. Both pilots were considered to be well trained because thay had participated in a previous display evaluation test in the same simulator.

DATA ANALYSIS

The pilots never looked at the turn and bank indicator, therefore, the following analysis was performed on the other three dial instruments, airspeed indicator, altimeter, and rate of climb meter. A data analysis program was written to evaluate the pilots' lookpoints on these conventional instruments in the following manner. The instrument coordinate system (n,y), whose origin was at the needle's origin, was rotated such that the n-axis coincided with the needle and the y-axis counting array was used such that for each 1/32 second that the lookpoint was within a 5 mm interval on an axis, a corresponding counter for that axis was incremented. A histogram of lookpoint for each axis was obtained for each landing approach and then summed together for each pilot then converted to probability density functions for presentation. In addition, dwell plots were made for each instrument. Every time a pilot looked at an instrument, a plot was generated showing where he looked on the instrument.

RESULTS AND DISCUSSION

It was postulated that if the pilots looked at the needle point of each instrument, that the probability density function of lookpoints would be normally distributed about the needle point with a standard deviation equal to the foveal radius. If this were true, the data would look like figure 4 for each of the instruments. Figure 4a is the probability density function along the axis of the needle pointer. Zero corresponds to the origin of the needle. The peak of the data should occur at the needle point (20 mm). Figure 4b is the probability density function normal to the needle axis. The peak should also occur at the needle point (0 mm).

Dwell Histograms

Figure 5 is a comparison of such plots for the two pilots using the airspeed indicator. Pilot A has a fairly sharp peak at 20 mm along the needle axis and between 5 and 10 mm normal to the needle axis. As mentioned previously, this corresponds closely to the needle point and the shape of the distribution curve is almost as expected. The tails of the curves are more extended than anticipated. Pilot B, however, has a much flatter distribution than expected as indicated by the lower peak and greater probability at the extremes of the plots.

A similar difference between pilots is true for the rate of climb instrument (fig. 6). However, for the altimeter (fig. 7) their probability density functions are quite similar with fairly broad peaks occurring at the origin of the needles. According to the original assumption, the distributions centered at the needles origin were not expected. In fact, the long tails of the distributions were also unexpected.

To evaluate the differences between predicted and actual results, additional plots of pilot lookpoints for these instruments were made for each time the pilot looked at each of these instruments. Typical plots for Pilot A of his looks at airspeed and rate of climb (figures 8a and 8b) show that he looked at the needle point. However, the plots for the altimeter were not consistent, some looks were directed at the needle point (fig. 8c) and some at the edge of the instrument (fig. 8d). It could not be determined why Pilot A adopted different scanning behavior with the altitude indicator. No consistent pattern was noted which might explain the changes in scanning strategy such as needle location, phase of flight, etc. Pilot B, however, consistently looked at the edge of the instrument closest to the main display as shown in figures 9a through 9c. It seems as if Pilot B's scanning strategy involved looking at a specific place for each instrument; lower right corner of the airspeed indicator and middle left edge of the altimeter and rate of climb indicator. The angular distance between the needle point and his lookpoints can be as much as 5 degrees, placing the needle point outside his foveal view. Therefore, at least two different instrument scanning strategies have been employed: looking at the instrument scanning needle point foveally (only Pilot A--presumably reading the numbers) and looking at the needle parafoveally (Pilot B and occasionally Pilot A, with the altimeter--presumably observing needle position to get an estimate of the quantity being displayed). See pilot comments for differences between pilots.

Dwell Time

Further analysis of the test data was made to see if there was a difference in average dwell times for the two pilots. The dwell times were statistically different for the two pilots ($\alpha < 1\%$). Pilot A spent 1/3 second whereas Pilot B spent only 1/4 second looking at the instruments. In addition, the dwell times in peripheral areas of the advanced flight director display were also different, 1/4 second for Pilot A versus 1/5 second for Pilot B. However, Pilot B had longer dwells looking at the center of the advanced sisplays, 9/10 versus 2/3 second.

Pilots' Comments

Unfortunately, this data analysis was done a few months after the tests were performed. However, both pilots were interviewed to get their impressions of why they looked where they did. Pilot A stated that he did "read" the numbers on the instrument and that he was sure this was a result of his pilot training. His instructor would cover an instrument and ask what the instrument read, wanting specific numbers and not general terms such as "in the green."

Pilot B responded that he was not aware of looking at the edge of the instruments and felt that he was doing his normal type of instrument cross-checks. He did acknowledge that he did feel pressure to stay close to the central display and not leave it for too long a time. In addition, part of his training had stressed the point of not looking at a cross-check for too long a period of time. It had been his experience that the instrument examiners would comment on long looks at a single instrument as being a sign of a lack of recent experience.

Discussion

Obviously, data from only two test subjects does not indicate that 50 percent of the pilots look at needle points and 50 percent look at instrument edges using parafoveal vision to get needle direction. But the data does show that these are at least two techniques that pilots use in extracting information from needle pointing instruments. It is not clear that one technique is any better than the other for accomplishing the mission. One technique appears to take less time and would thus allow more time for other tasks. However, the other technique should provide the pilot with more accurate information. The genesis of these two techniques are not yet known. It could be a matter of training by instructors or it could be physiological in that one pilot has more acute peripheral vision. Further investigation of these techniques should be performed to investigate the advantages, if any, of one technique over the other and methods of training for such techniques if advantages are found.

On last comment should be made about a possible reason for the differences noted. The left eyes of these pilots were tracked. It is not known how precisely the two eyes track together. The general assumption has always been made that they do track together, but no data exist on this subject. If there is any lag between the two eyes for one pilot and not the other, this might account for the differences noted. This eye tracking phenomena should be investigated and documented.

CONCLUDING REMARKS

It has been shown in this preliminary analysis that there are at least two methods of scanning electro-mechanical instruments, looking at the needle point and looking at the edge of the instrument for a shorter period of time. Initial analysis of pilot comments and dwell times indicate that this difference is due to different pilot scanning techniques. These techniques should be investigated further to delineate the advantage of one over the other, and methods of training these techniques to pilots.

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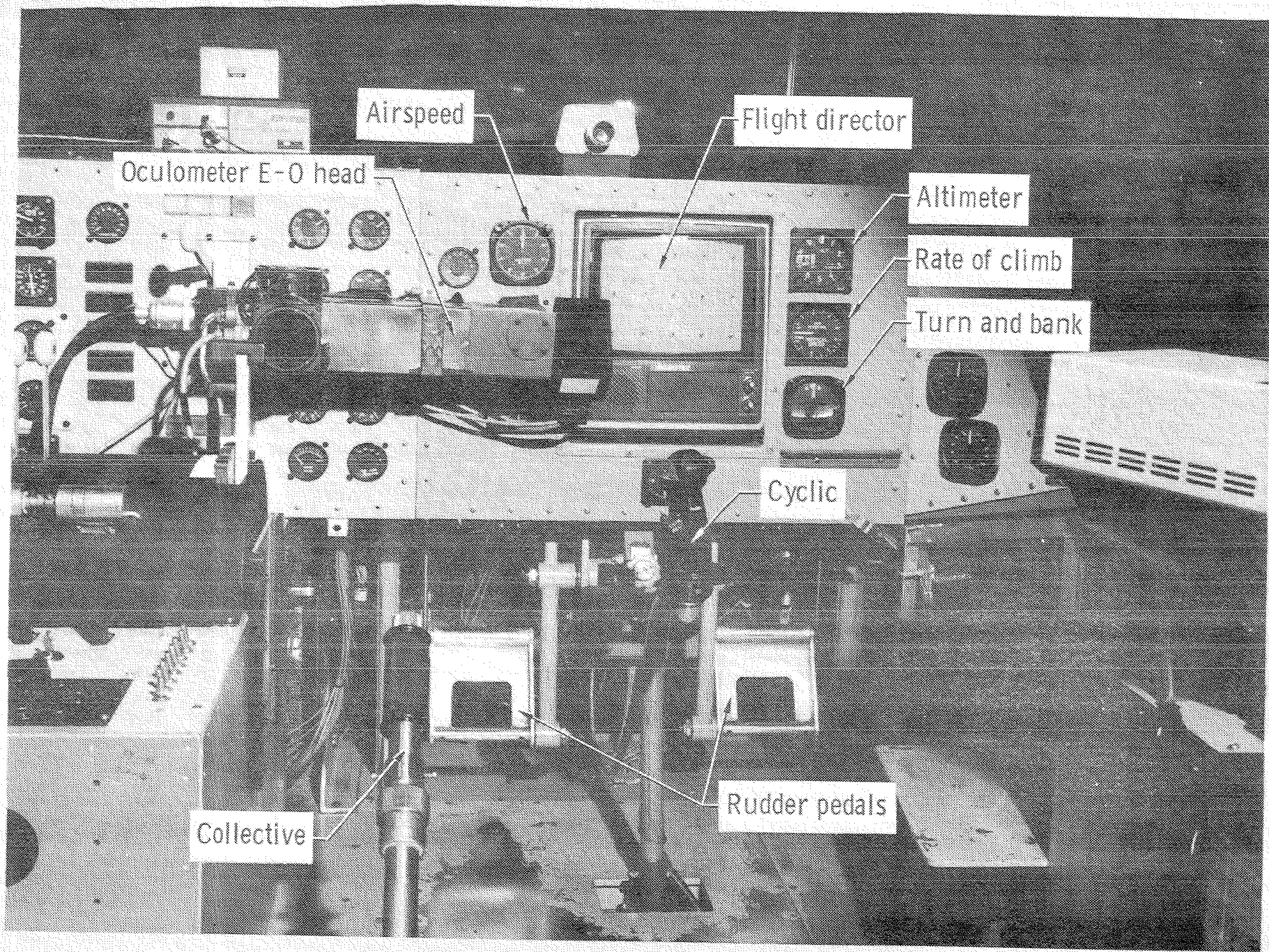


Figure 1. - Cockpit arrangement of oculometer, instruments, and controls.

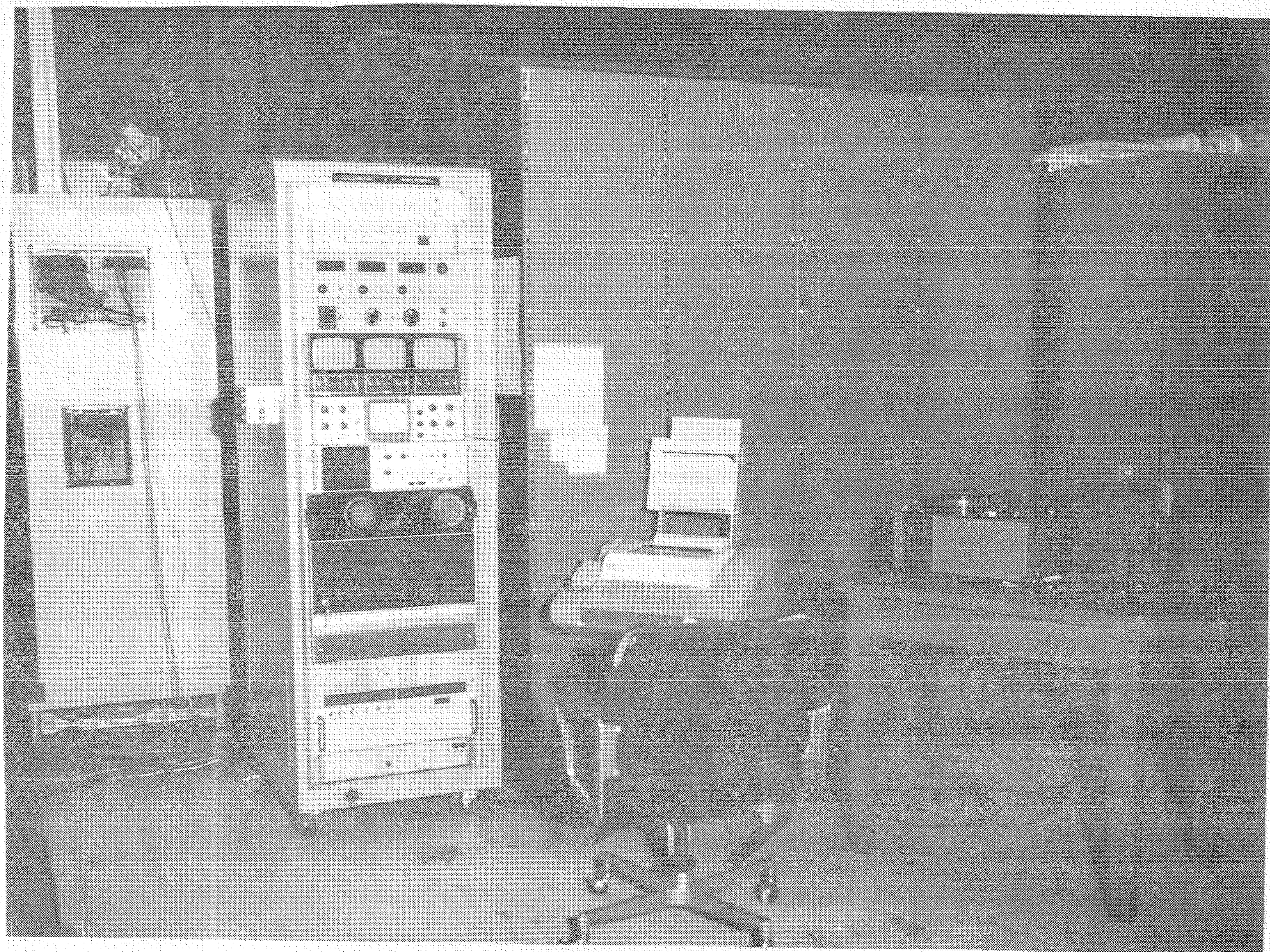


Figure 2.- Oculometer computer and associated video equipment.

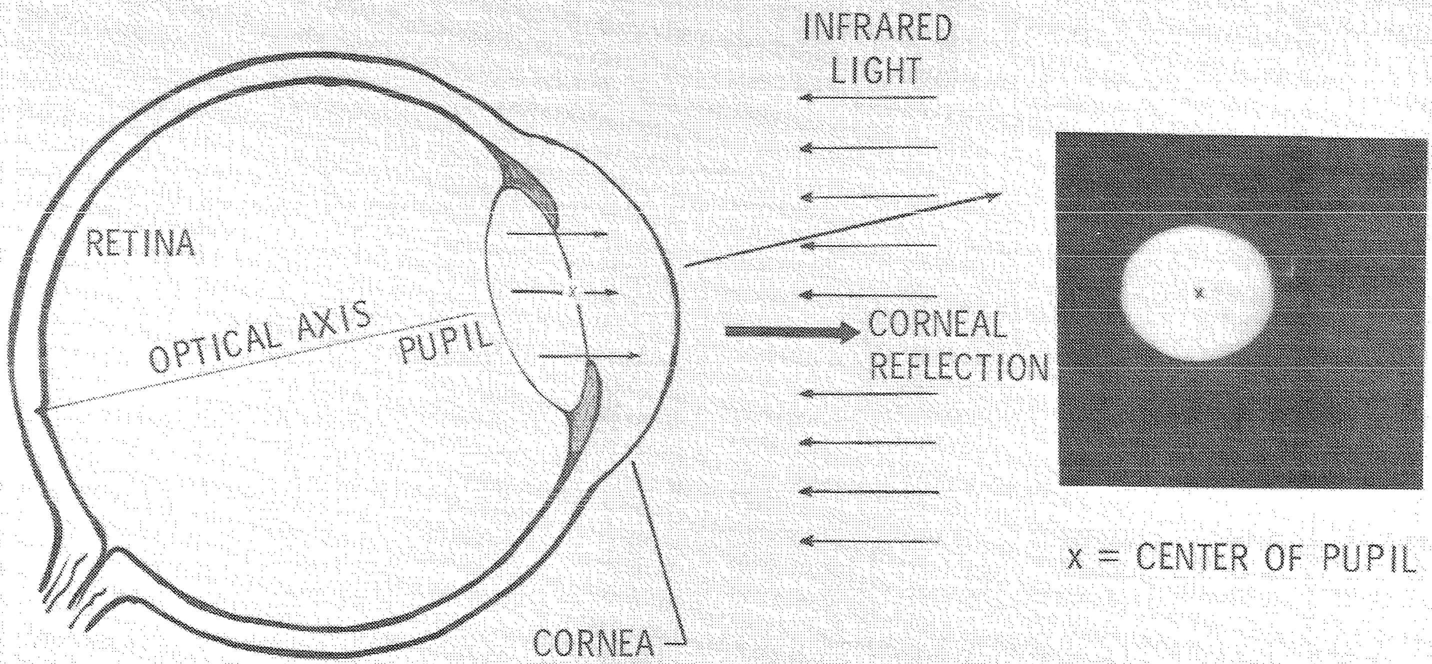


Figure 3. - Oculometer operating principle.

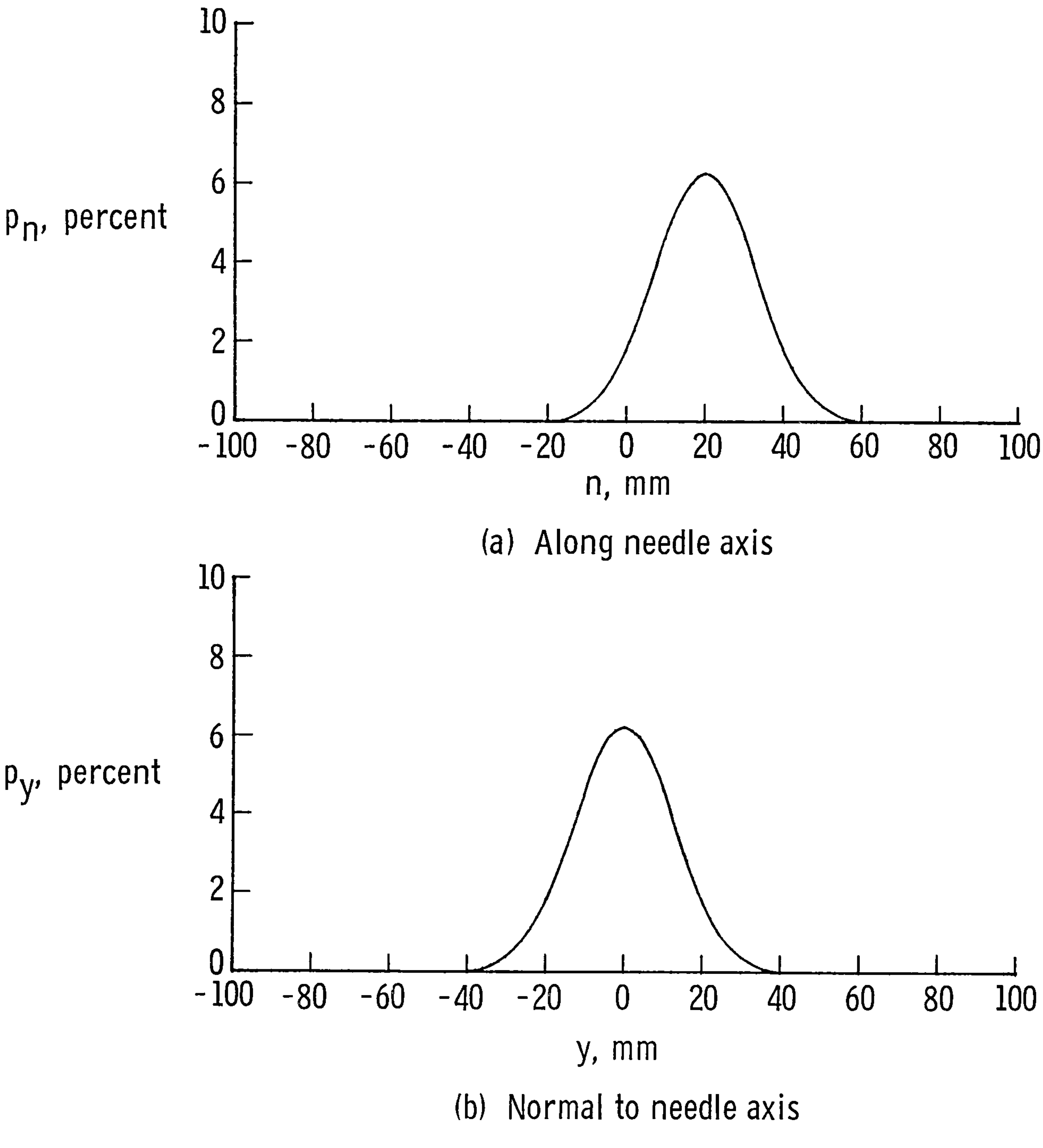


Figure 4. - Predicted density function along and normal to needle axis.

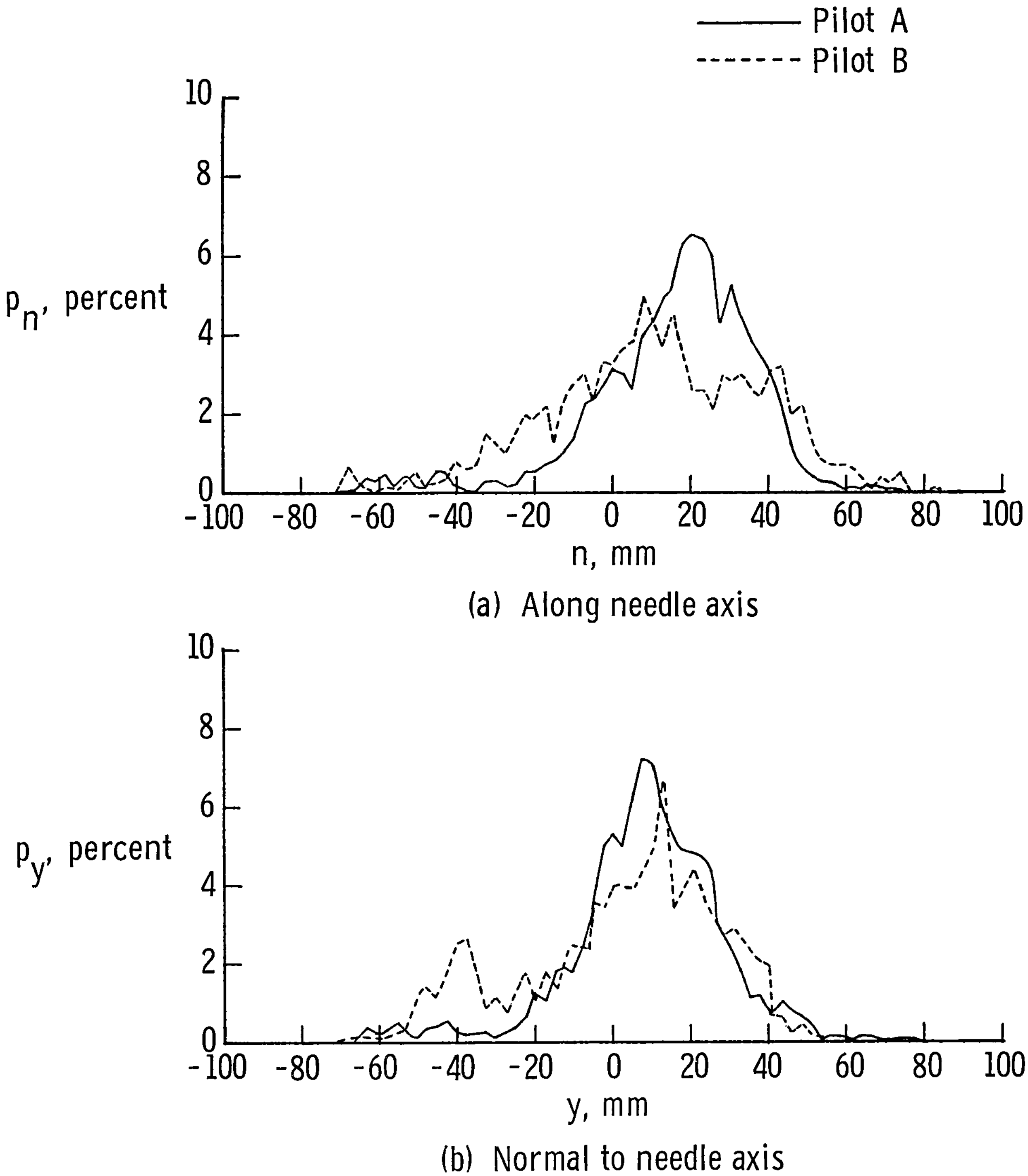


Figure 5. - Probability density function along and normal to needle axis for airspeed instrument.

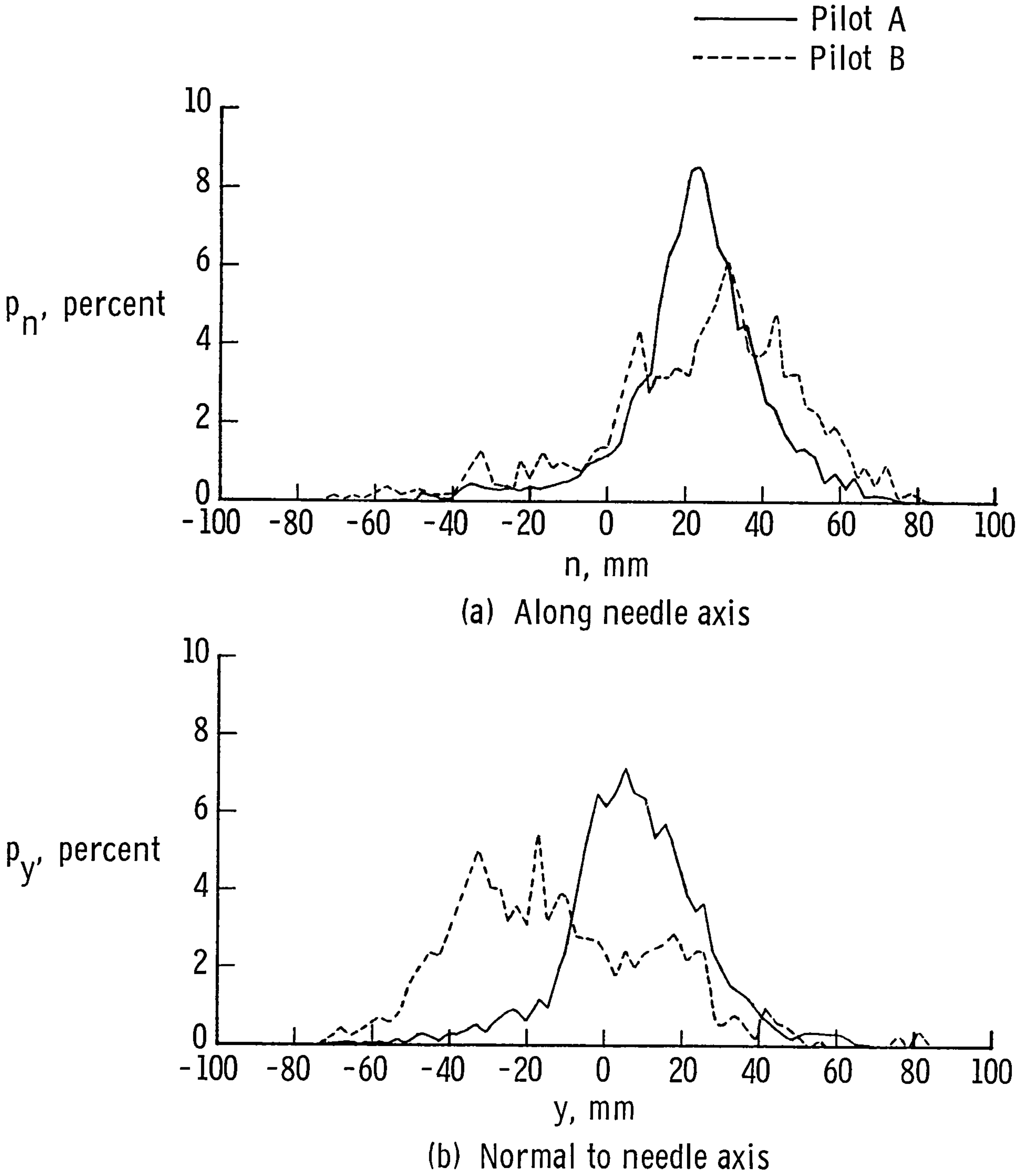


Figure 6. - Probability density function along and normal to needle axis for rate of climb instrument.

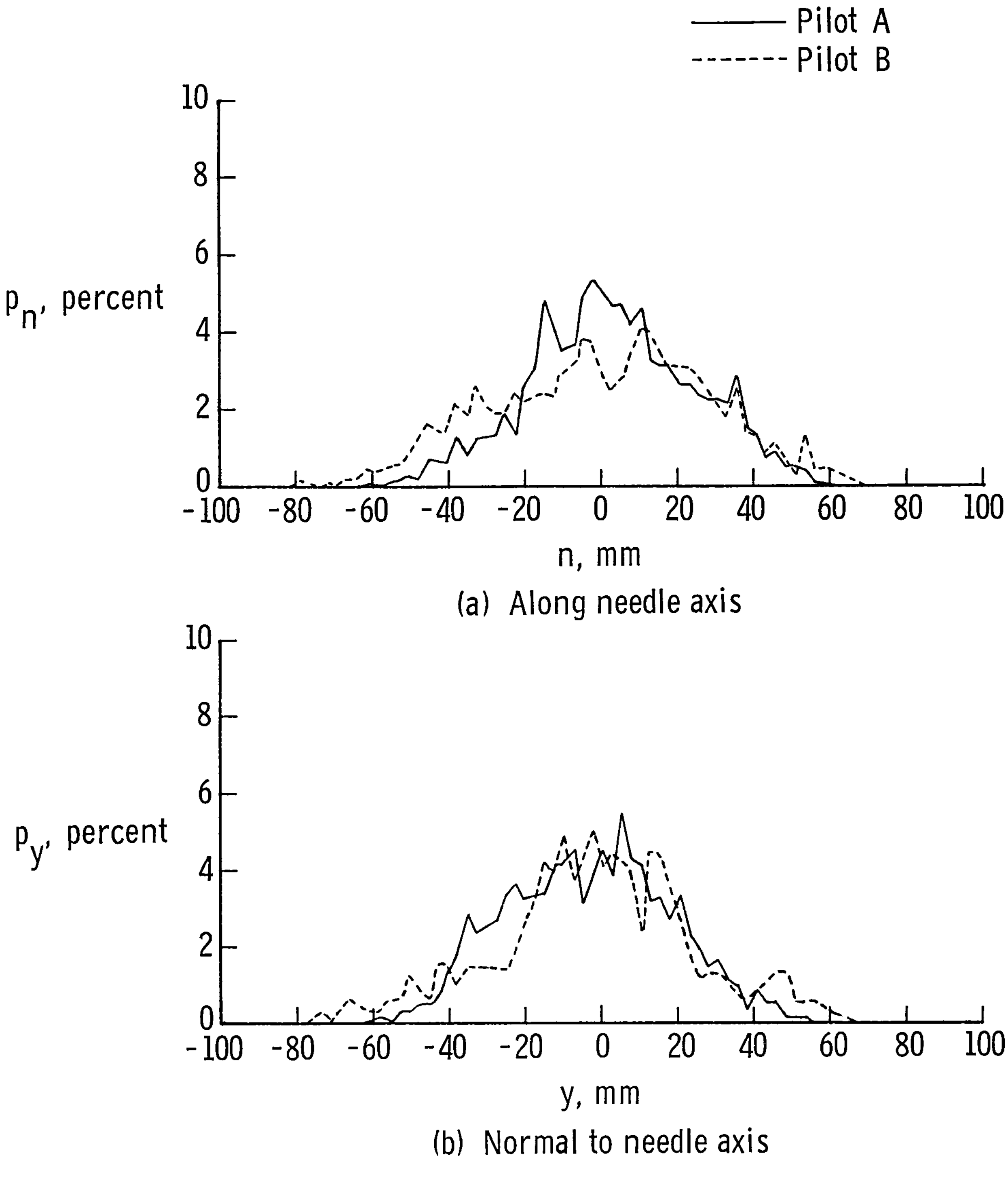
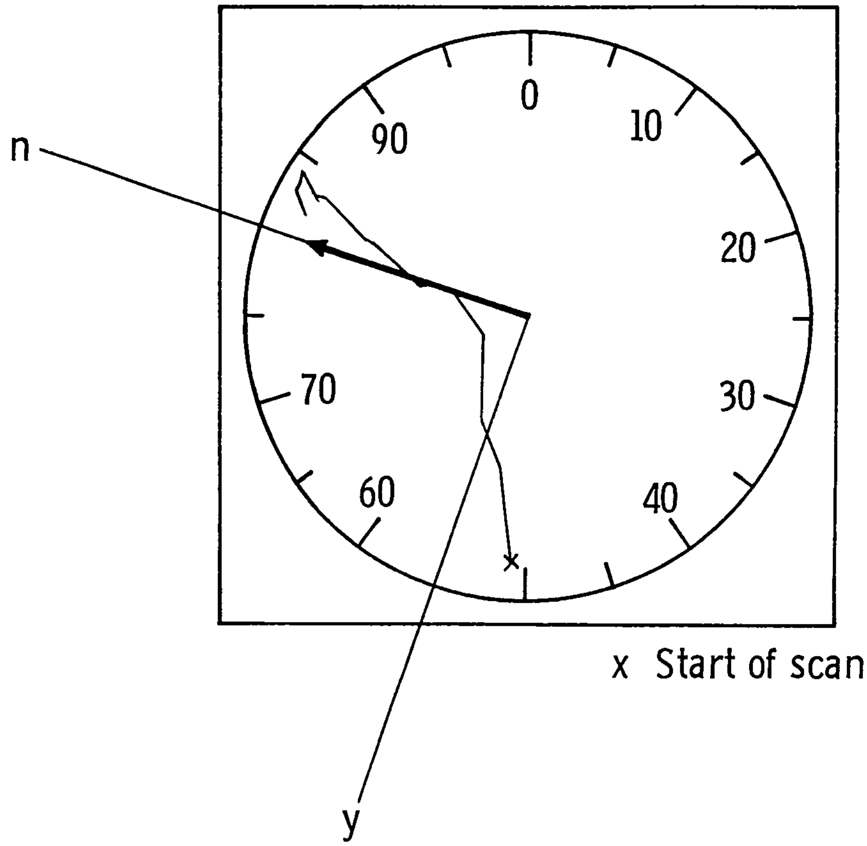
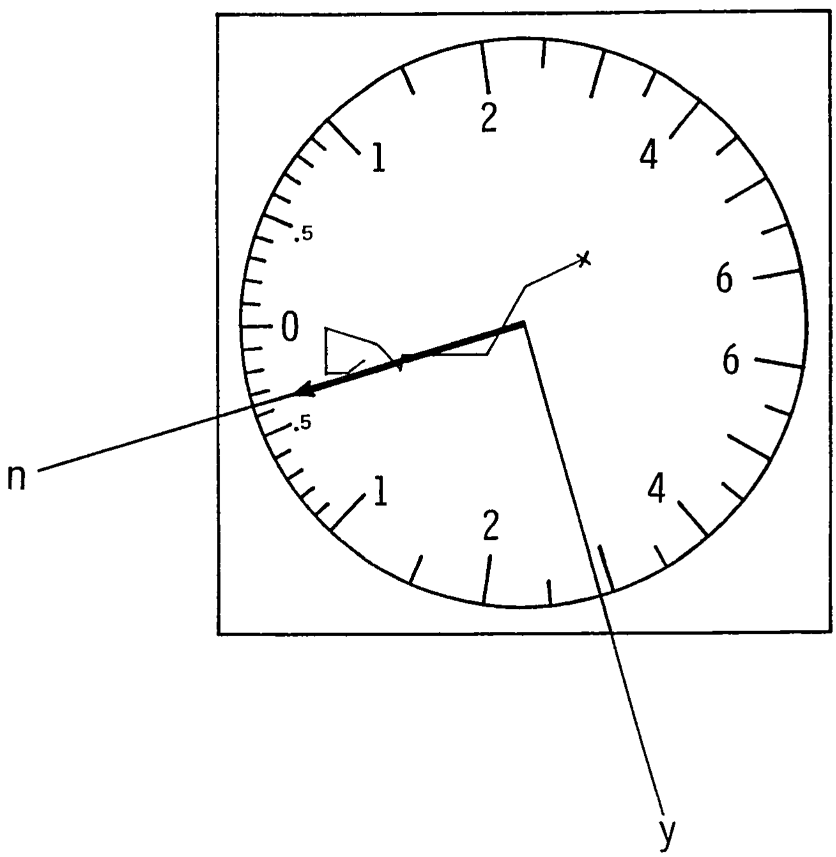


Figure 7.- Probability density function along and normal to needle axis for altimeter instrument.



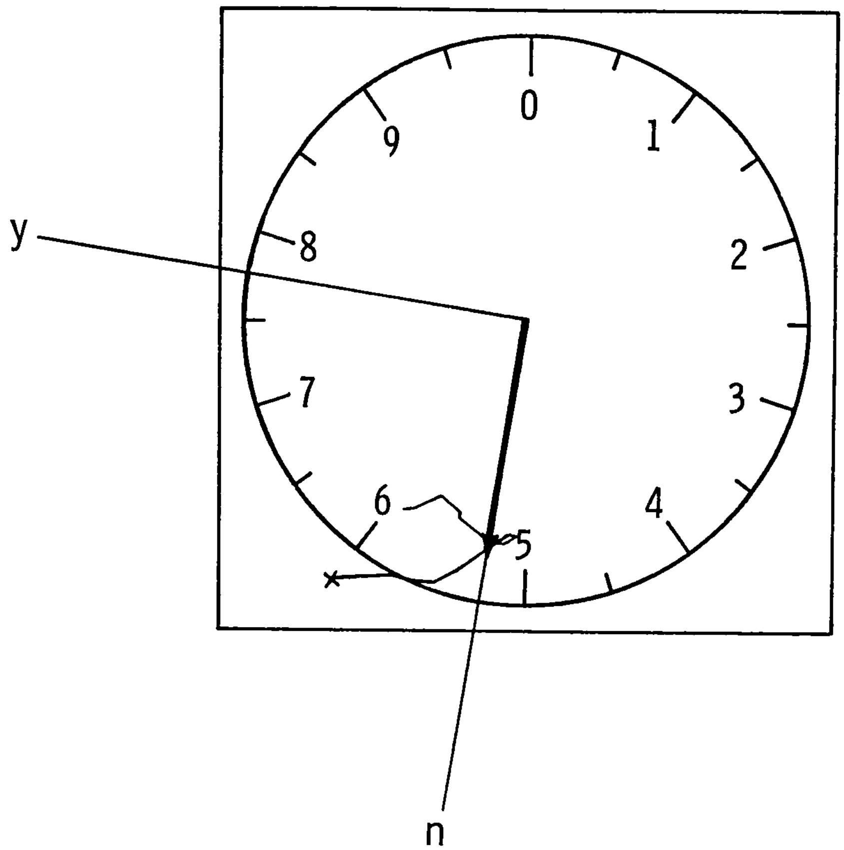
(a) Airspeed indicator

Figure 8. - Pilot A typical look at peripheral instruments.



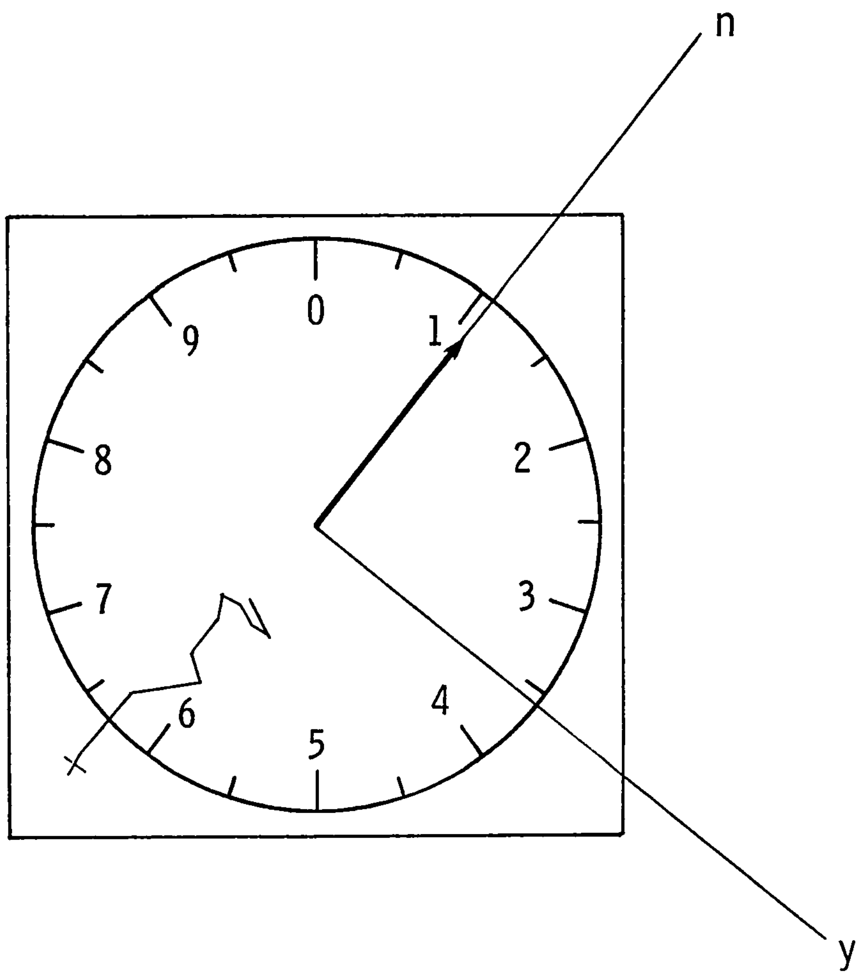
(b) Rate of climb indicator

Figure 8. - Continued.



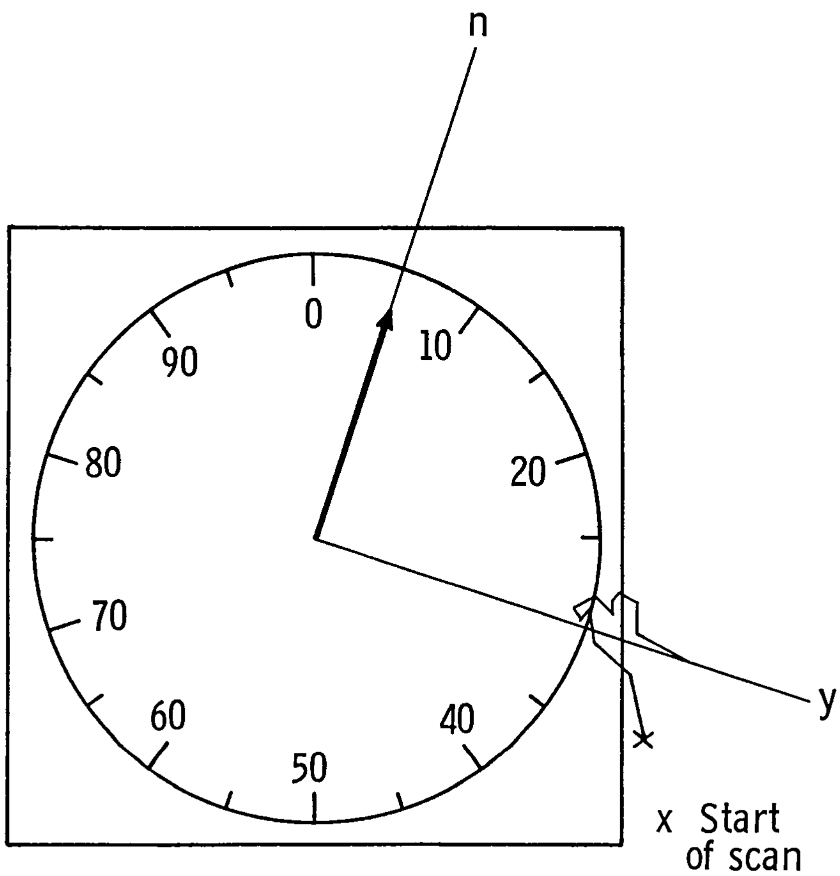
(c) Altimeter

Figure 8. - Continued.



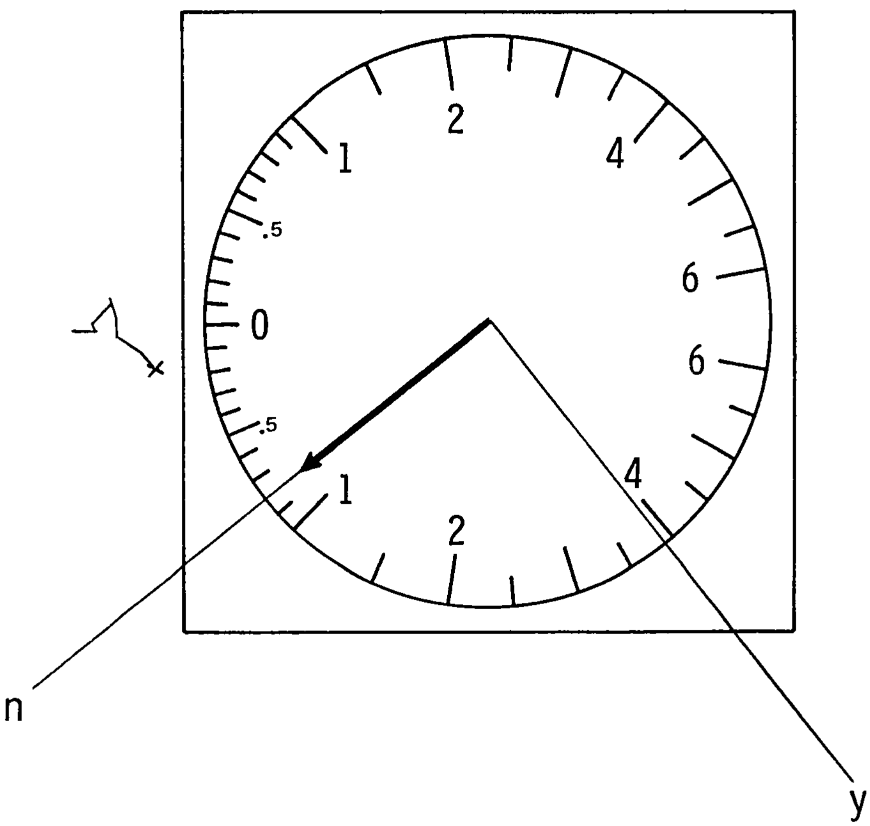
(d) Altimeter

Figure 8. - Concluded.



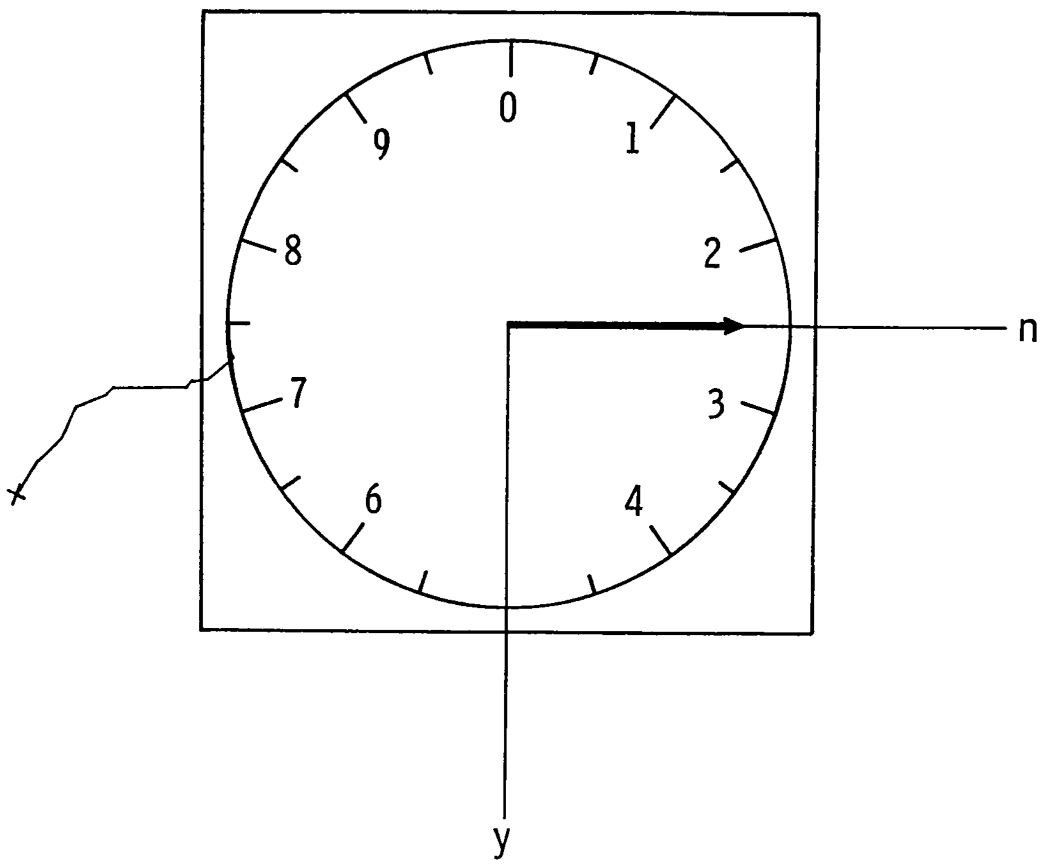
(a) Airspeed indicator

Figure 9. - Pilot B typical look at instruments.



(b) Rate of climb indicator

Figure 9. - Continued.



(c) Altimeter

Figure 9. - Concluded.

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15 Supplementary Notes

16 Abstract

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