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THE USE OF STANDARD FLIGHTS AND MOTION PHOTOGRAPHY IN THE ANALYSIS OF AIRCRAFT PILOT PERFORMANCE

by

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and

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A report on research conducted at the University of Pennsylvania, Philadelphia, Pennsylvania, by means of a grant-in-aid from the National Research Council Committee on Selection and Training of Aircraft Pilots from funds provided by the Civil Aeronautics Administration.

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Committee on Selection and Training of Aircraft Pilots

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LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington, D. C.
Division of Anthropology and Psychology

Committee on Selection and Training of Aircraft Pilots

May 14, 1943

Dr. Dean R. Brimhall
Director of Research
Civil Aeronautics Administration
Washington, D. C.

Dear Dr. Brimhall:

The attached report on The Use of Standard Flights and Motion Photography in the Analysis of Aircraft Pilot Performance by M. S. Viteles and A. S. Thompson, is submitted by the Committee on Selection and Training of Aircraft Pilots with the recommendation that it be included in the series of technical reports published by the Division of Research, Civil Aeronautics Administration.

The report deals with the early phases of the program of research conducted at the University of Pennsylvania. In it are presented the principles and procedures of standard flights, which have become basic in the research program of the Committee. The report also presents a description of the techniques used in photographic analysis of flight performance and the findings of early research involving the use of motion photographs obtained during standard flights.

The report is essentially a progress report of work completed in 1940. However, the procedures described by the authors have been employed in subsequent investigations which will be covered in reports soon to be made available for publication by the Division of Research, Civil Aeronautics Administration.

Cordially yours,

Morris S. Viteles, Chairman
Committee on Selection and
Training of Aircraft Pilots
National Research Council

MSV:sw

Editorial Foreword

Early in 1940 there was initiated at the University of Pennsylvania a research program designed primarily to furnish objective criteria of flight performance. One of the major outcomes of this program was the development of Standard Flights which have been used extensively in many investigations conducted under the auspices of the Committee on Selection and Training of Aircraft Pilots for standardizing the flight situation during research. In addition, the standard flight has found its way into the pilot training program as an aid in setting up uniform conditions for the measurement of progress in training.

The second major outcome of the University of Pennsylvania research program has been the application of motion photography in recording and evaluating the performance of the pilot during standard flights. Methods have been devised for analyzing such records qualitatively and quantitatively in order to arrive at reliable indices of pilot performance.

The attached report, submitted as a Progress Report in October 1940, describes the basic procedures of the standard flight and of motion photography and analysis and presents preliminary findings obtained in the quantitative analysis of records obtained during standard flights. The methods described in this report are basic to other studies to be published in the technical series issued by the Division of Research, Civil Aeronautics Administration. It seems desirable to publish the present report at this time so as to provide a necessary background for the consideration of data to be presented in such subsequent reports.

There is also presented, as a Supplement, a bulletin originally prepared for the Division of Research, Civil Aeronautics Administration, representing a manual of standard check flight procedures for Civilian Pilot Training.

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SUMMARY

In this report of the University of Pennsylvania Research Project is presented a description of preliminary research undertaken; (a) to provide objective criteria of success in learning to fly; (b) to provide objective data on co-ordinated patterns of limb and body movements which lead to optimal plane control; and (c) to use these data in formulating practical guides for flight instructors.

Four major steps were taken in this investigation:

(1) The basic maneuvers of the CPT primary course were combined into a series of Standard Flights in order to provide standardized flight test situations during which the flying habits of pilots could be observed or recorded.

(2) During standard flights an investigator accompanying the pilot analyzed the flying habits of pilots and evaluated the flight performance on the basis of direct observation during flight. Flights were made with 8 flight instructors and 5 students piloting an Aeronca Chief (a wheel-type plane) and 7 flight instructors piloting a Piper Cub (a stick-type plane). Each of the three groups was divided into "superior" and "inferior" sub-groups and comparisons made of their flying habits (in terms of methods of handling the controls).

(3) Motion photographs were taken of the flight performance of 8 subjects while each was piloting an Aeronca Chief through six maneuvers selected from the standard flights. The camera field included the instrument panel, the control wheel, and the lower arms and hands of the pilot.

The motion photographs were analyzed by two methods: (1) direct inspection during slow-motion projection, resulting in observations on methods of grasping and handling the controls; and (2) measurement of successive aileron and elevator control positions during frame-by-frame projection, resulting in detailed data on control movements during the maneuvers. The frame-by-frame readings were plotted graphically, and the graphs analyzed by inspection and by the computation of quantitative indices descriptive of the control movements.

Comparisons were then made between the indices obtained by the group of four "superior" and the group of four "inferior" pilots as previously classified by the method of direct observation.

(4) Detailed introspective reports of experiences during each instruction flight were prepared by a research assistant while taking the first ten hours of primary flight instruction.

The results of the investigation may be summarized as follows:

(1) The data obtained by the methods of direct observation during flight and direct inspection of motion photographs during slow-motion projection revealed characteristic habits of pilots in terms of posture, methods of grasping the controls, and methods of manipulating the controls. Certain movements, such as the use of wrist, finger and slight arm movements in preference to full arm movements were found to differentiate the "superior" and "inferior" pilots used in the investigation.

(2) Analysis of the graphs and the quantitative indices resulting from treatment of the frame-by-frame readings of control positions revealed characteristic differences between the "superior" and "inferior" pilots when the graphs and mean scores on the indices were compared.

With the exception of the 90° medium turns, significant differences between the two groups were found in each of the flight maneuvers (Take-Off, Straight and Level Flight, 360° Left Power Turn, and Landing) in the case of one or several of the five Control Movement Ratios used as quantitative indices, namely Total Amount of Control Movement, Percent of Total Time in Motion, Number of Control Movements, Changes in Direction of Control Movements, and Discontinuity of Control Movements. For example, the "superior" pilots were found to exhibit a greater amount of elevator control movement (Index 1) during the 4 seconds preceding the moment of landing while the "inferior" pilots exhibited a greater amount of aileron control movement during Take-Off. A detailed comparison of the two groups in terms of these indices is presented in the report.

(3) Analysis of the introspective reports made during flight instruction revealed observations with respect to the orientation of a beginning student, recognition of cues, the development of skills, and specific difficulties encountered by the individual making the reports. To the extent that these observations are "typical" of students in general they represent an interesting source of data relevant to problems of training.

The investigation must be considered merely as preliminary to further research and the specific findings subject to the limitations set by the small number of cases. Its chief value lies in its exploratory nature and in the development of research tools and techniques such as the use of motion photography of flight performance, the methods of analysis of the photographic records, and the Standard Flights. The importance of the Standard Flight both as a research and as a field technique has led to the preparation of a Manual of Standard Flight Procedures which is presented as a Supplemental Report.

Part I

AIMS and PROCEDURES

AIMS OF THE UNIVERSITY OF PENNSYLVANIA RESEARCH PROJECT

The University of Pennsylvania Research Project has been devoted to a study of the movements made by pilots in controlling the plane during flight. The immediate purpose of this study was to investigate the patterns of limb and body movements characterizing pilots with varying degrees of proficiency in maintaining flight attitude. The ultimate aims of the study are: (1) to provide objective criteria of success in learning to fly, to be employed both (a) in gauging the progress of student pilots, and (b) in evaluating the effectiveness of procedures used in selecting student pilots; (2) to provide objective data on the co-ordinated patterns of limb and body movements which lead to optimal plane control; and (3) to use these data in formulating practical guides for flight instructors, in the form of step-by-step procedures to be employed in training pilots to perform maneuvers included in the Civilian Pilot Training Program.

PROCEDURES USED IN THIS STUDY

Four major steps were taken in the development of the University of Pennsylvania Research Project:-

I. Standard Flights.

The first step involved the preparation of standard flights,[1] of varying complexity, as a device for enabling the investigator to make observations on different pilots under the same general conditions. The development of these standard flights was based upon the assumption that records of movements and performance of different pilots can have no practical usefulness in research unless they are obtained under essentially uniform conditions. Each standard flight is a "work-sample" that calls for prescribed critical maneuvers to be carried through in a definite order under stated conditions. The standard flights provide in the air analogues of the trade-tests for motor vehicle operators which have been used so effectively in selecting and training both civilian and military motor-vehicle operators.

II. Evaluation of Flying Habits and Plane Performance by Direct Observation.

The second step in the preliminary phase of the study involved the development and use of a standard procedure for the evaluation of pilot flying habits and plane performance by an investigator accompanying the pilot during flight.[2] This procedure provided a basis for noting the character of limb and body movements of pilots maintaining various degrees of "goodness" of flight. It employed essentially the method of direct observation, within a standard frame of reference, for analyzing the details of limb and body movement during flight as a means of discovering differences existing among pilots with varying degrees of proficiency in maintaining flight attitude.

The procedure for the evaluation of flying habits and plane performance involved the use of the two forms shown on pages 4 and 5. The investigator accompanied the pilot during standard flights and, on the basis of direct observation, entered on these forms comments such as those appearing in the sample protocols presented in Exhibits 1 and 2, pages 4 and 6.

The pilots used as subjects were classified in order of proficiency on the basis of an evaluation of the observations on plane performance during the flight,

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[1] Described on pages 19-20 and in the Supplemental Report.

[2] Described in detail in Appendix A.

EXHIBIT 1

Subject: L Weeks (41 hours) Field: Phila Airport

Date: May 9, 1940 Wind: 3 - 5, somewhat bumpy

Plane: Aeronca

Record Sheet for Analysis of General Flying Habits

I. HANDLING OF CONTROLS:

A. Posture:

Position: Sat erect

Changes of Position: Sways away from turns; moves about a good deal.

B. Throttle:

Grasping: Ball in palm, three fingers near lock

Moving: Uses fingers for slight changes; palm for rapid changes.

Use of Lock: Didn't use.

Variations: None; removed hand for only a moment.

C. Rudder:

Position of Feet: Heels on floor; ball of feet on pedals.

Changes of Position: None.

Extent of Leg Movements: Moved legs occasionally from side to side.

D. Wheel:

Grasping: Top center of wheel with fingers grasping loosely and thumb extended along rim.

Variations in Grasping:

None; except for use of both hands for a moment in 1500' climb and in Figure 8.

Moving Ailerons: Loose wrist, some wrist + finger, mostly arm.

Moving Elevators: Short, jerky, whole arm movements; frequent, slight in-and-out movements

EXHIBIT 2

Subject: L. Weeks

Date: May 9, 1940.

Record Sheet for Analysis of General Flying Habits:

II. Evaluation of Flight: Over-all Rating:
Excellent
Good
Average
Fair
[✓ Poor]

A. Following Course:

1. Altitude: Held in flight A; lost 150' in 1st 720; fluctuated in 8's.

2. Maneuvers: Followed course.

3. Approaches: Satisfactory

4. Landings: 1st - Tail landing and bounce
2d - Tail landing and bounce within 150'

B. Turns:

1. Entry: Poor; Tail dropped + plane seemed to resist starting turn.

2. Bank: Fairly constant in left 720°; poor in others.

3. Rate: Varied in climbing turns; fairly constant in others.

4. Recovery: Rather abrupt, but usually on course.

C. Angle of Climb and Glide: Varied considerably during 1500' climb.

D. Straight and Level Flight:

1. Constancy of Attitude: Poor, especially bobbing of nose on horizon.

2. Extent of Control Adjustment: Extensive, especially in slight elevator adjustment.

E. Throttle Control: O.K.

F. Traffic Check: Fair.

G. Comments:

as illustrated in Exhibit 2. The subjects were then divided into two groups, termed "superior" and "inferior". This classification was further checked by conference with the local director of the Civilian Pilot Training Program.[3]

The flying habits of pilots classified as "superior" and "inferior" on this basis were then directly compared by means of entries such as those illustrated in Exhibit 3 on pages 7 to 9 , inclusive. From these tables of classified observations, the flying habits which were common to both groups and those which differentiatedthe "superior" from the "inferior" group were determined.

This method of direct observation and accompanying evaluation of flying habits and plane performance was employed in three studies involving, respectively, 8 flight instructors in Philadelphia piloting an Aeronca Chief, 7 flight instructors at College Park, Maryland, and Bloomington, Indiana, piloting a Piper Cub, and 5 recently licensed University of Pennsylvania students piloting an Aeronca Chief. A detailed report on the procedures and results of the three studies is presented in Appendix A.[4]

III. Motion Photography and Micromotion Analysis.

A. General Features

The third step in this investigation involved the use of motion photography and of the techniquesof micromotion analysis in recording and classifying body and limb positions and movements used in controlling the plane during flight. In addition to the examination of these details during "slow speed" projection, procedures were devised for graphically representing and analyzing, in quantitative terms, the amount, direction, independence or simultaneity, and similar characteristics of wheel and wheel-column movements used in effecting aileron and elevator adjustments.

B. Camera and Field

For motion-picture photography, a Filmo camera, Model 141A, was mounted on a tripod in the space behind the right front seat of a Stinson 105 plane. The tripod was held firm by means of a heavy spring attached to the floor and by a clamp extending from the head of the tripod to a tube along the side of the cockpit. A 15-mm. lens, located 41-1/4 inches from the instrument board, provided a camera field including the instruments on the left side of the instrument board (airspeed, turn and bank indicator, and tachometer), the wheel and throttle, and the upper legs, lower arms, and hands of the subject. Cine-Kodak Super-X Panchromatic Safety Film was used. The camera was operated at a speed of 16 frames per second in photographing all maneuvers except 360° Power Turns, where the speed was

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[3] In the two studies using flight instructors as subjects, the classification by local directors agreed perfectly with that of the investigator in the case of the Aeronca Chief group, and confirmed the investigator's classification in the case of the Piper Cub group with the exception of a reversal of placement involving 2 subjects.

[4] The method of direct observation for the evaluation of flying habits and plane performance is also being used in studies at New Orleans, La., and Rochester, N.Y., formulated jointly by H. M. Johnson, of Tulane University, H. A. Edgerton, of Ohio Stat University, and M. S. Viteles, of the University of Pennsylvania. These studies involve the use of rating scales, graphic recording devices, and direct observation during standard flights. No results are as yet available from these studies. It is assumed that a separate report will be made after each investigator has had an opportunity to examine the data obtained in the research centers at Tulane University and Rochester.

EXHIBIT 3*

VII. Classification of Flying Habits of Subjects: (X indicates that the item of behavior was exhibited by the subject.)

A. POSTURE:

	Erect	Sway with Turns	Cocked Head During Turns	Body Back & Forth During Landing
Superior Group:				
Subject 1	X	X	X (360°)	
Subject 2	X	X (very little)		
Subject 3	X	X (very little)		
Subject 4	X	X		
Inferior Group:				
Subject 1	X	X		X
Subject 2	X	X		
Subject 3	X	X	X	
Subject 4	X	X		

B. THROTTLE:

1. Method of Grasping:

	Ball in Palm	Between Fingers and Thumb	Used Finger for Slight Movements	Used More Than One Method of Grasping
Superior Group:				
Subject 1	X		X	
Subject 2	X		X	
Subject 3		X	X	X
Subject 4	X	X	X	X
Inferior Group:				
Subject 1	X	X	X(occasionally)	X(irregular change)
Subject 2	X		X	
Subject 3	X		X	
Subject 4	X	X	X	X(regular change)

2. Released Throttle During Flight:

	720° Turns	90° Turns	Figure 8's	Climb to 1500'	Landing	Irregularly
Superior Group:						
Subject 1	X		X		X	
Subject 2					X(few sec.)	
Subject 3	X					
Subject 4	X					
Inferior Group:						
Subject 1	X		X		X	X(no constant method
Subject 2						
Subject 3						X(constant method but irregular release)
Subject 4	X	X	X	X	X	

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*From Appendix A - Analysis of General Flying Habits of Pilots.
A. Instructors Piloting a Wheel-Type Plane

EXHIBIT 3 (Continued)

C. RUDDER:

	Heels Off Floor During Taxi	Heels on Floor During Flight	No Leg Movements Except in Taxi
Superior Group:			
Subject 1	X	X	X
Subject 2	X	X	X
Subject 3	X	X	X
Subject 4	X	X	X (slight)
Inferior Group:			
Subject 1	X	X	X (slight)
Subject 2	X	X	X
Subject 3	X	X	X (slight)
Subject 4	X	X	X

D. WHEEL:

1. Location of Hand on Wheel:

	Grasped Wheel at Center	Grasped Wheel Toward Left Side	Grasped Wheel At Left Side
Superior Group:			
Subject 1	X		
Subject 2		X	
Subject 3	X	X	X (taxi)
Subject 4	X	X	
Inferior Group:			
Subject 1			X
Subject 2	X	X	X
Subject 3	X	X	X
Subject 4	X		X (few sec.)

2. Use of Both Hands on Wheel:

	720°'s	Fig. 8's	Landing	Irregularly	Not at All
Superior Group:					
Subject 1	X	X	X		
Subject 2			X(few sec.)		
Subject 3	X				
Subject 4	X				
Inferior Group:					
Subject 1	X	X	X		
Subject 2					X
Subject 3				X	
Subject 4					X

3. Frequency of Shifting Position:

Superior Group:

Subject 1 - least
Subject 2 - only in 720°'s
Subject 3 - regular shifts from side to center
Subject 4 - occasional (slight)

Inferior Group:

Subject 1 - occasional
Subject 2 - occasional
Subject 3 - frequent
Subject 4 - occasional

EXHIBIT 3 (Concluded)

D. WHEEL: (Continued)

4. Movement of Ailerons:

	Mostly Wrist & Fingers	Slight Arm	Mostly Arm
Superior Group:			
Subject 1	X		
Subject 2		X	
Subject 3		X	
Subject 4		X	
Inferior Group:			
Subject 1			X
Subject 2			X
Subject 3	X	X	
Subject 4		X	

5. Movement of Elevators:

	Fingers & Thumb for Slight Pressure	Arm Movement for Greater Pressure
Superior Group:		
Subject 1	X	X
Subject 2	X	X
Subject 3	X	X
Subject 4	X	X
Inferior Group:		
Subject 1		X
Subject 2	X	X
Subject 3		X
Subject 4	X	

6. Methods of Grasping During Flight:

	Fingers Around Wheel - Thumb Toward Body	Palm Down With Center Bar Between Fingers	Between Thumb and Finger Only	Grasped Around Center Bar	Finger Tips Resting on Wheel
Superior Group:					
Subject 1	X				
Subject 2	X				
Subject 3		X (flight)			
Subject 4	X	X			X(during long run)
Inferior Group:					
Subject 1	X				
Subject 2	X				
Subject 3		X	X	X	
Subject 4	X	X	X(few sec.)	X	

reduced to 8 frames per second.

C. The Main Experiment Involving Motion Photography and Micromotion Analysis

1. Subjects. The main experiment, involving the use of motion photography and micromotion analysis, included 8 subjects. Of these, 7 were flight instructors[5] in the Philadelphia area and the other a recently licensed University of Pennsylvania pilot. All had participated in the investigation involving the evaluation of flying habits and plane performance by the method of direct observation referred to on pages 3 to 6 of this report and in Appendix A.

2. Maneuvers. Each subject was photographed while piloting the plane through six separate maneuvers taken from the standard flights and combined into one flight. The maneuvers included:-

a. Take-Off
b. Straight and Level Flight for 15 seconds
c. 90° Medium Left Turn
d. 90° Medium Right Turn
e. 360° Left Power Turn
f. Landing

The beginning and end of each maneuver were indicated on the film by flashing a light into the lens.

3. Comparing the Control Movements of "Superior" and "Inferior" Pilots. The findings of the experiment involving the use of direct observation for the evaluation of flight attitude[6] were used in classifying these 8 subjects into two groups of 4 "superior" and 4 "inferior" pilots, respectively, the licensed student pilot being grouped, on the basis of observed performance, with the 3 "inferior" flight instructors. The photographic records of control movements during each maneuver were then analyzed, by means of the techniques described below, to determine the respects in which body and limb positions and control movements of "superior" pilots resembled or differed from those of "inferior" pilots.[7]

4. Visual Inspection of Films Projected at Reduced Speed. As a first step in the use of motion photography in comparing the "superior" and "inferior" pilots, each film was projected by means of an especially adapted Keystone A-81 Projector which makes possible slow-speed projection without flicker. Such a projector creates a slow-motion effect even in the case of photographs taken at 8 frames per second. The chief purpose of this projection was to observe the general pattern of movement and, more particularly, to study in greater detail items of behavior, such as finger movements, changes in wheel and throttle grasp, etc., which can be more fully observed through the use of motion photography and slow projection than by direct observation during flight.

During the slow-motion projection, the investigator recorded his observations on body and limb positions and on movements made by "superior" and "inferior"

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[5] One flight instructor who acted as a subject in the preliminary experiment involving the evaluation of flying habits and plane performance by direct observation during flight (pages 3 to 6 of this report and Appendix A) was not available when the motion pictures were taken.

[6] See pages 3 to 6 of this report and Appendix A.

[7] See footnote, page 12.

pilots, respectively, on the form used for the evaluation of general flying habits illustrated in Exhibit 1 of this report. The flying habits of "superior" and "inferior" pilots, as observed during the slow-motion projection of photography, were then compared by means of the technique employed in the evaluation of flying habits, used in connection with direct observation, described in pages 3 and 6 of this report. Results obtained from the observation during slow-motion projection are summarized in Part II of this report.

5. Procedures in Micromotion Analysis of Photographic Records. For micromotion analysis, the photographs were projected, frame by frame, by means of the adapted Keystone A-81 Projector, onto graph paper lined 10 spaces to the inch, the graph paper being turned so that the vertically ruled lines were parallel to the wheel-column in the projected photographs.

Measuring and Plotting Wheel Movements in Aileron Control:- In order to analyze turning movements of the wheel to the left and right, providing aileron adjustments, the position of the wheel in each frame was measured by counting the number of spaces on the graph paper between the following points of reference: (1) an assumed line running longitudinally through the center of the wheel-column (indicated by the letter "X" on photograph B, Exhibit 4), and (2) the tip of the right corner of the wheel (indicated by the letter "Y" on photograph B, Exhibit 4).

Because of the closeness of the camera to the wheel, the distance between these two points of reference varies with changes in the wheel-column position, the distance increasing as the wheel is pulled back, i.e., closer to the camera, even without turning of the wheel. In order to eliminate this artifact, photographs were taken of the wheel when slowly moved from full forward to full back position with the wheel held constant, that is, free of turning movements, in the position which maintains ailerons in neutral.[8] Photographs were taken of the wheel-column in 71 planes and measurements were made of the distance between the X and Y points on the wheel (photograph B, Exhibit 4) in each of these planes. Finally, readings in successive planes were combined to give 13 "base" readings indicating the distance between X and Y points on the wheel, with the wheel in neutral position, for each of 13 wheel-column positions located at approximately equal intervals between full forward and full back positions.

The final index of wheel position was then obtained by subtracting the observed distance (in number of graph squares) between the two points of reference from the appropriate "base". The numbers representing these wheel positions range from minus 10 through 0 to plus 10. Since a figure preceded by a minus sign always indicates a wheel position to the left of neutral and a plus sign a wheel position to the right of neutral, these have been converted into a range from left 10 through 0 (Neutral) to Right 10 and plotted in this manner. The readings of lateral wheel position for photographs A, B, and C, Exhibit 4, are R 6.5, L 8.0, and L 3.5, respectively.[9]

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[8] The reading between the two points of reference was 25 when the wheel-column was full forward and 30 with the wheel-column full back.

[9] It is recognized that this method provides only a partial correction for the angle at which the pictures were taken, since it does not correct for the fact that a reading of one space (on the graph) does not represent the same amount of difference in position when the wheel-column is far forward as it does when the wheel-column is drawn well back. However, since this factor is significant only in the extreme wheel-column movements such as are found in Landing and Take-Off, and in view of the fact that the error, under any circumstances, is relatively small, it seemed undesirable to undertake, during this initial project, the extensive work required for the calculation of a more refined index.

The manner of plotting successive changes in wheel position is well illustrated in Graph Ib (following page 41). Here it may be seen that the "inferior" pilot starts the Take-Off run with the wheel slightly left of neutral, as indicated by a reading of Left 1, and during the Take-Off run continues to move the wheel irregularly toward the left, attaining a maximum reading of Left 8. Toward the middle of the Take-Off run, the wheel is returned to close to the neutral position represented by an index of Left 2 but, in contrast to the performance of the "superior" subject shown in Graph Ia, there continue to be irregular movements of the wheel to the left and extending over to the right of neutral until the moment of leaving the ground. The rapid movement of the wheel at the moment of leaving the ground also appears strikingly on this graph, the readings[10] changing from Left 5 to Right 8 within a period of approximately 3/8 of a second.

Measuring and Plotting Movements in Elevator Control:- In order to analyze movements of the wheel-column in adjusting the elevators during various maneuvers, positions of the column in successive frames were plotted by counting the number of spaces on the graph paper between two points of reference on the photograph: (1) the point of entry of the wheel-column into the instrument board (indicated by the letter "X" on photograph C, Exhibit 4), and (2) the end of the column to which the wheel is attached (indicated by the letter "Y" on photograph C, Exhibit 4).

As the wheel is pushed forward to lower the elevators, the distance on the graph between the two points of reference is reduced. The numbers indicating wheel-column positions range from 15 (wheel-column full forward) to 56 (wheel-column full back) with 34 or 35 representing the neutral position, depending upon the weight of the load in the plane. In other words, a low number indicates that the wheel-column is forward and the elevators are in the lowered position; a high number indicates that the wheel-column is pulled back and the elevators are in the raised position. For example, the numerical reading of wheel-column position for photograph A, Exhibit 4, is 18.5; for photograph B, 36.5; for photograph C, 49.0.

The manner of plotting successive changes in wheel-column positions is shown on Graph Ia. Here it is apparent that at the beginning of the Take-Off run the "superior" pilot holds the wheel-column toward the full back position, since the initial reading is 43.5. The wheel-column is held behind the neutral point for about 3 seconds and then gradually moved forward, beyond the neutral position, to a forward position indicated by the number 24. It is then gradually returned to approximately the neutral position until the moment previous to leaving the ground, when the wheel-column is drawn back rather rapidly.

Analysis of Graphs:- Graphs of wheel movements (for aileron adjustment) and of wheel-column movements (for elevator adjustment) were plotted for each of the maneuvers performed by each pilot.[11] Readings were made of alternate frames, in other words, of frames representing photographs taken at the rate of 4 per second for the 360° Left Power Turn (actually photographed at the rate of 8 per second) and of frames representing photographs taken at the rate of 8 per second for the other maneuvers (actually photographed at the rate of 16 per second).

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[10] Since the photographs analyzed on Graph I were taken at 16 frames per second and alternate frames read, every change in position represents one occurring within 1/8 of a second.

[11] With the exception of a few cases where the finished photographs displayed imperfections which made analysis impossible. These cases explain occasional variations in the number of subjects in the reports on individual maneuvers.

EXHIBIT 4

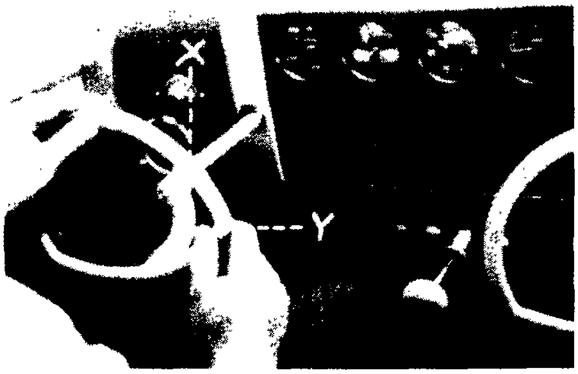
PHOTOGRAPH A

TAKE-OFF

Wheel Reading - R6.5
(Aileron)

Wheel-Column
Reading - 18.5
(Elevator)

PHOTOGRAPH B

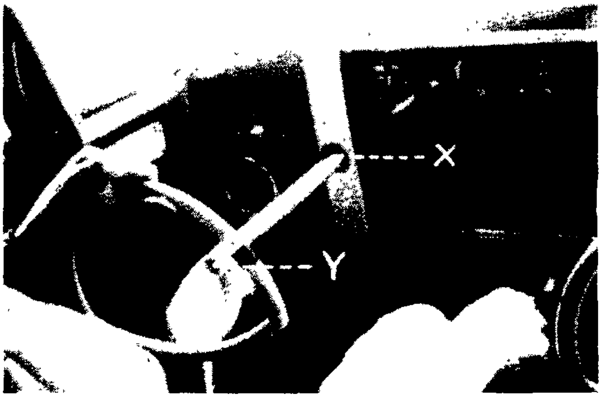


360° LEFT POWER TURN

Wheel Reading - L8.0
(Aileron)

Wheel-Column
Reading - 36.5
(Elevator)

PHOTOGRAPH C



LANDING

Wheel Reading - L3.5
(Aileron)

Wheel-Column
Reading - 49.0
(Elevator)

Visual Inspection of Graphs:- As a first step in the analysis of graphic records, all graphs were first inspected in order to discover general patterns in the way of nature, extent, and regularity of movements during a maneuver; and such other gross characteristics as may be observed through direct visual inspection. Examples of findings based on such inspection are found in the description of wheel and wheel-column movements, during Take-Off, of a "superior" and "inferior" pilot, respectively, presented on pages 11 and 12 . The general findings arising out of the application of this procedure are to be found in Part II of this report.

Quantitative Treatment of Graphic Data:- Visual inspection of graphs was supplemented by quantitative methods of analysis. One simple method of quantitative analysis is to count the number of squares between adjacent points on a graphic record as a means of stating numerically the amount of movement of the wheel to the left or right, or of the wheel-column forward or backward, during the intervening 1/8 second. The same procedure can be applied to cover longer periods of time.

For example, on Graph Ia it was found that during the 3/8 second immediately subsequent to the moment of leaving ground the "superior" pilot moved the wheel from position L 4.5 to position L 4, indicating a range of movement (towards the right) of .5 graphic squares during this stage of flight. In contrast, during the 3/8 second following the moment of leaving ground the "inferior" pilot moved the wheel from position L 5 to R 8, indicating, during this stage of flight, a range of movement (towards the right) reprsented by 13 graphic squares.

Similarly, a simple quantitative technique was used to determine the tendency toward simultaneity or independence of control movements. This was done by calculating the number of instances in which the wheel and wheel-column were moved simultaneously, as compared with the number in which the wheel and wheel-column were moved independently. Such a count, for example, in the case of Graph IIa shows that 51.5 per cent of control movements of the "superior" pilots were simultaneous, in the sense that both controls were moved at the same moment of time, while the parallel figure for the "inferior" pilot, represented in Graph IIb, is 18.7 per cent.

Control Movement Ratios:- In addition to the calculation of simple quantitative indices of the type described above, an effort was made to study wheel and wheel-column quantitatively through the calculation of five specific Control Movement Ratios. These are as follows:

INDEX 1: TOTAL AMOUNT OF CONTROL MOVEMENT

Index 1 was calculated by running a "map measure" along the graphed line plotted to show wheel movement, (affecting aileron adjustment), and the line plotted to show wheel-column movement, (affecting elevator adjustment). This provides a measure of the total length of the line representing movement (i.e. successive positions) of the control. In order to compensate for differences in total time of the maneuver as carried through by various pilots, the obtained measure was divided by the length of the straight line across the graph, which would be obtained in plotting if the control were held in a constant position, without movement, throughout a maneuver. The resulting ratio is an index of the Total Amount of Movement of the control.

For example, the Total Amount of Wheel Movement for the "superior" pilot (Graph Ia) is represented by the figure 1.148, while that for the "inferior" pilot (Graph Ib) is 1.414. Corresponding ratios of Total Amount of Wheel-Column Movement are 1.209 and 1.444, respectively. It is apparent, therefore, that the "inferior" pilot moved both the aileron and elevator controls more than did the "superior" pilot during the Take-Off maneuver.

INDEX 2: PER CENT OF TOTAL TIME IN MOTION

Since differences in Total Amount of Control Movement may be due either to extended but infrequent movements or to restricted but frequent movements of the wheel or wheel-column, an Index 2 was computed to show the proportion of the total time during which the control was in movement during the maneuver. This was obtained by counting the number of readings in which the position of the control differs from its position in the preceding frame. Dividing by the total number of readings for the maneuver, i.e. by the total number of frames read, gives a Control Activity Index representing the total percentage of time in which the control was in movement during a maneuver.

In Graph Ia the Control Activity Index for the "superior" pilot in the case of wheel movement proved to be 50.7 per cent and for the "inferior" pilot, 72.8 per cent. Corresponding indices for wheel-column movement were 39.9 per cent and 66.0 per cent, respectively. In other words, both the wheel (affecting aileron — adjustment) and the wheel-column (affecting elevator adjustment) were kept in motion during a larger proportion of the time taken for the maneuver by the "inferior" pilot than by the "superior" pilot.

INDEX 3: NUMBER OF CONTROL MOVEMENTS

Index 3 provides a quantitative statement of the total number of discrete control movements during the manuever. These movements are of four types: from left to right, right to left, stationary to left, and stationary to right, in the case of wheel movements; and forward to back, back to forward, stationary to forward, and stationary to back, in the case of wheel-column movement.

Index 3 was obtained by dividing the total number of wheel movements or of wheel-column movements by the total number of readings for the maneuver. In other words, it provides essentially an index of the average number of discrete control movements during each 1/8 second, except in the case of the 360° Left Power Turn where the index shows an average number of discrete control movements for each 1/4 second.[12]

In Graphs Ia and Ib, Index 3 for wheel movements (affecting aileron adjustment) proved to be .372 for the "superior" pilot and .383 for the "inferior" pilot. Index 3 for wheel-column movements (affecting elevator adjustment) proved to be .209 for the "superior" pilot and .401 for the "inferior" pilit. In other words, while the two pilots have approximately the same average number of wheel movements per 1/8 second in making aileron adjustment, the "inferior" pilot averaged approximately twice as many wheel-column movements per 1/8 second in making elevator adjustments.[13]

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[12] Since the index is obtained by dividing the total number of control movements by the total number of readings, it is apparent that the index for no movement is 0.00, and that if a discrete movement were made every 1/8 second during flight (or every 1/4 second during the 360° Left Power Turn), the index would be 1.00.

[13] It appears to the investigators that the index is of value as a specific indication of number of discrete control movements. However, it possibly becomes a greater significance when Index 3 is compared with Indices I and 2. Such a comparison, referring to the wheel movements of the "superior" and "inferior" pilot during the Take-Off maneuver, Graphs Ia and Ib, indicates that although the "inferior" pilot makes no more discrete movements than does the "superior", these are more extended in range since Index 1 and 2, respectively, for the "inferior" pilot are higher than Index 1 and 2, respectively, for the "superior" pilot. Such inter-relationships as indices have not been examined in detail in the study to date, but there is reason to believe that such an examination represents a promising further line of attack on the problem.

Index 3 represents a quantitative statement of the number of discrete control movements without reference to direction. It seemed desirable to extend the quantitative treatment by a break-down of Index 3 into two additional indices obtained through a consideration of direction of movement. These are:-

INDEX 4: CHANGES IN DIRECTION OF CONTROL MOVEMENT

Index 4 shows whether the control movement persists in a given direction, in the sense of being consistently maintained in that direction, or is marked by intermittent regressive movements in the opposite direction. This index was computed, for aileron adjustment, by first counting the number of times the direction of the wheel movement was reversed, and for elevator adjustment by counting the number of times there was a reversal in the direction of the movement of the wheel-column, except where such reversals occurred after an interval without movement of 2/8 second or more.[14] The obtained number of reversals of direction was then divided by the total number of readings. The index therefore represents the average number of regressive movements for each 1/8 second in the case of all maneuvers except the 360° Left Power Turn, where the index represents the number of regressive movements every 1/4 second.

Referring again to Graphs Ia and Ib, it was found that the index of changes in direction of wheel movement (affecting aileron adjustment) proved to be .284 for the "superior" pilot and .299 for the "inferior" pilot. In the case of wheel-column movements (affecting elevator adjustment) the figures showing number of changes in direction of control movement proved to be .142 and .297 for the "superior" and "inferior" pilots, respectively. This comparison indicates no difference between the "superior" and "inferior" pilot with respect to the persistence of movement in a given direction in the case of aileron adjustment, but a greater number of changes of direction of movement (affecting elevator adjustment) in the case of the "inferior" pilot.

INDEX 5: DISCONTINUITY OF CONTROL MOVEMENTS

A provisional index of Discontinuity of Control Movements was calculated by subtracting Index 4 from Index 3. When this subtraction is made, the resulting number is an index of the frequency of two kinds of movements: (1) discontinuous movements in the same direction, i.e. movements in a single direction separated by an interval without movement, in other words movements giving a step-like ascending or descending graph, and (2) movements from a stationary position in a direction opposite to the direction of the previous movement. The latter cannot be considered reversals in direction since there has been an intervening period without movement.

The value of the index resulting from the subtraction of Index 4 from Index 3 is determined, in the main, by the first kind of movement described above, that is, by the number of discontinuous movements in the same direction. Occasionally, however, the value is inordinately influenced by the incidence of the second type of movement described above. For this, and other reasons, Index 5 is not an entirely satisfactory measure of discontinuity of movement.

In general, however, the index shows the average number of discrete discontinuous movements in the same direction for each 1/8 second for all maneuvers

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[14] There is a more or less constant error in this index inasmuch as changes in direction of movement required by the maneuver were not eliminated in counting the total number of changes in direction. However, since the former are very few in each maneuver, this may be considered as a negligible element for the purposes of the present study.

except the 360° Left Power Turn, where the index refers to discrete discontinuous movements in the same direction for each 1/4 second. In Graphs Ia and Ib, Index 5 for wheel movements (affecting aileron adjustment) was .088 in the case of the "superior" pilot, and .105 for the "inferior" pilot. In the case of wheel-column movements (affecting elevator adjustment), Index 5 proved to be .067 for the "superior" pilot and .104 for the "inferior" pilot.

Data Obtained from Calculation of Control Movement Ratios:- Typical data obtained by calculating control movement ratios are presented in Graphs I to VI, inclusive. With each graph are included the five control movement ratios for the stated maneuver as performed by a "superior" and "inferior" pilot, respectively.

Results obtained through the calculation of control-movement ratios have been considered together with the results obtained through the application of other procedures described on the preceding pages to arrive at the findings listed in Part II of this report, devoted to a discussion of the Outcomes of the University of Pennsylvania Research Project.

IV. Introspective Reports on Learning How to Pilot a Plane

In addition to the procedures described above, the assistant attached to this research project, Albert S. Thompson, prepared for each instruction flight a detailed introspective report of experiences on learning to pilot a plane, extending from the first dual flight through the first solo flight. These introspective reports are summarized on pages 37 to 41 in Part II, and samples are presented as Exhibits 9 and 10, pages 38 and 39 .

Part II

MAJOR OUTCOMES

MAJOR OUTCOMES OF THE UNIVERSITY OF PENNSYLVANIA RESEARCH PROJECT

I. Standard Flights.

One of the major outcomes of the University of Pennsylvania Research Project was a series of standard flights. Three such standard flights, designated as A, C1, and C2, respectively, were developed. Diagrammatic plans of these standard flights are presented in Exhibits 5, 6, and 7 on pages 20 to 22 , inclusive. Standard Flights A and C1 have been used extensively both at the University of Pennsylvania and at other research centers.

Each standard flight included "critical maneuvers" representing those which were being investigated, and "transition maneuvers" representing those employed to place the plane in position for the succeeding "critical maneuver". Standard Flight A included "critical maneuvers" suitable for use in determining the proficiency of student pilots who had completed Stage A of instruction (dual flight), viz. Taxiing, Take-Off, Climbing, Straight and Level Flight, 90° Right and Left Turns, Glide, and Landing. Standard Flights C1 and C2 represented flights suitable for use in observing the performance of student pilots nearing the completion of Stage C (final stage of solo flight). Critical maneuvers in Standard Flight C1 included 720° Power Turns with 60° Bank and Figure 8's around Pylons, in addition to Take-Off, Straight and Level Flight, Climbing Turns, 180° Side Approach and Precision Landing. More complex maneuvers, learned during the later stages of instruction, such as Power-On Stall, Power-Off Stall, Spiral Climbs, Spiral Approach and Side-Slip during Landing, were included in Standard Flight C2.

As indicated above, the standard flights developed in connection with the University of Pennsylvania Research Project have been used not only at the University of Pennsylvania but also in research jointly directed by H. M. Johnson, H. A. Edgerton, and M. S. Viteles, and conducted at Tulane University and in Rochester; and in research directed by H. A. Edgerton and R. Y. Walker, at Ohio State University; by A. W. Williams, at the University of Maryland; by E. B. Greene, at the University of Michigan; and by W. N. Kellogg, at Indiana University. They have also been made available to E. L. Kelly of Purdue University, who is proposing to use them in connection with his work. There seems reason to believe that the standard flights represent a significant contribution to the Aircraft Pilot Research Program. Program[15].

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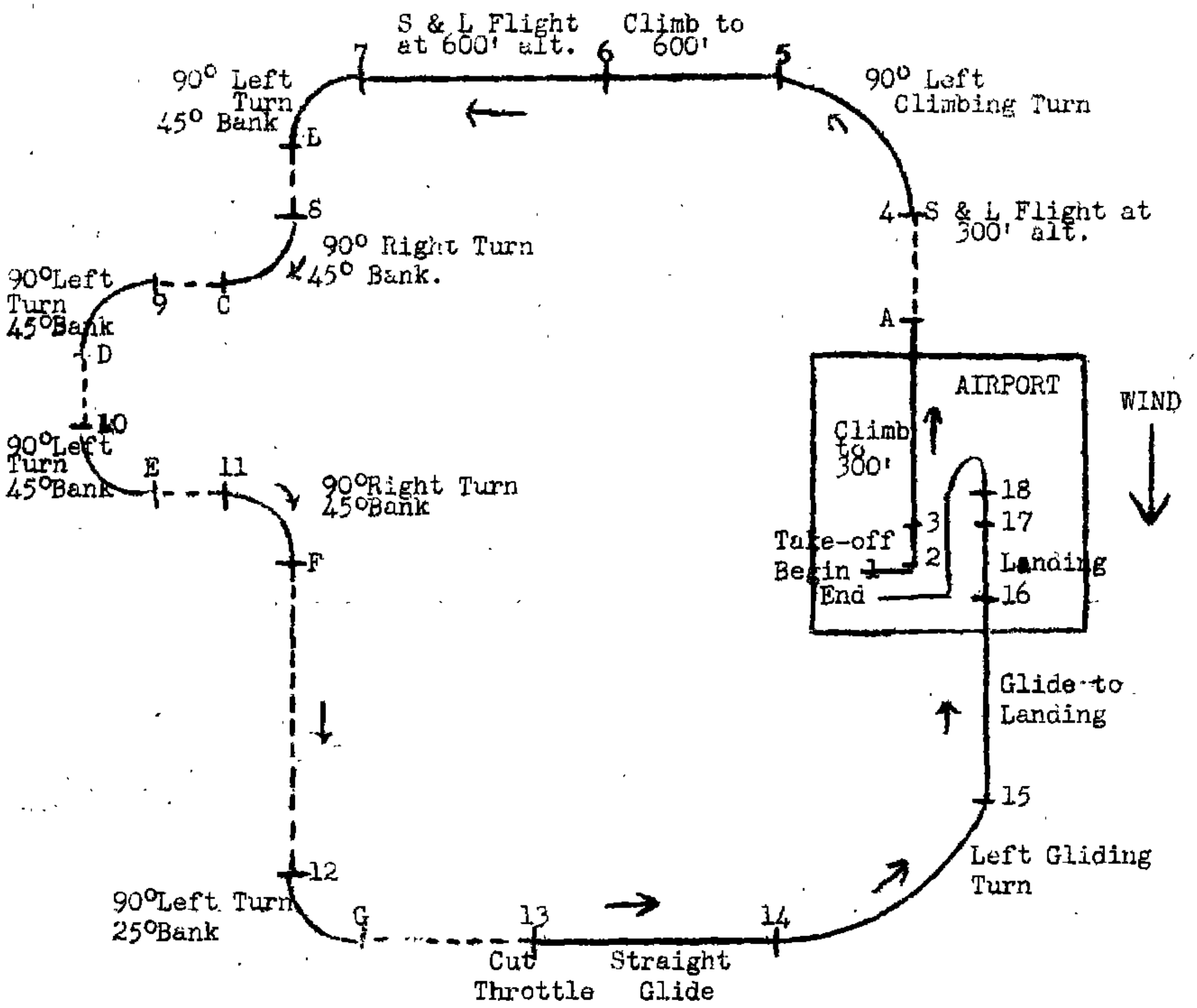
[15] Editor's Note: Since the original date of this report (October 1940) standard flights have become an integral part of the Committee's research program. Standard Flights A, C1, and C2 have been expanded into a series of four flights designed to test student pilots at each of the four stages of primary C.P.T. instruction. The latter series is being used in the coordinated Boston and Midwest Projects of 1942 and 1943 in which flight performance is observed directly as well as through photographic records. The general principle of standardization of the flight test situation has also found its way into actual field practice both in the United States and abroad.

A discussion of the standard flight technique, a description of a series of flights of increasing difficulty, and suggestions for adaptations of the standard flights to individual airports and for specific uses have been added to this report as a Supplemental Report, entitled Manual of Standard Check Flight Procedures for Civilian Pilot Training (January 1943).

EXHIBIT 5

DIAGRAM OF STANDARD FLIGHT A

(For the S. Davis Wilson Airport, Phila., Pa.)



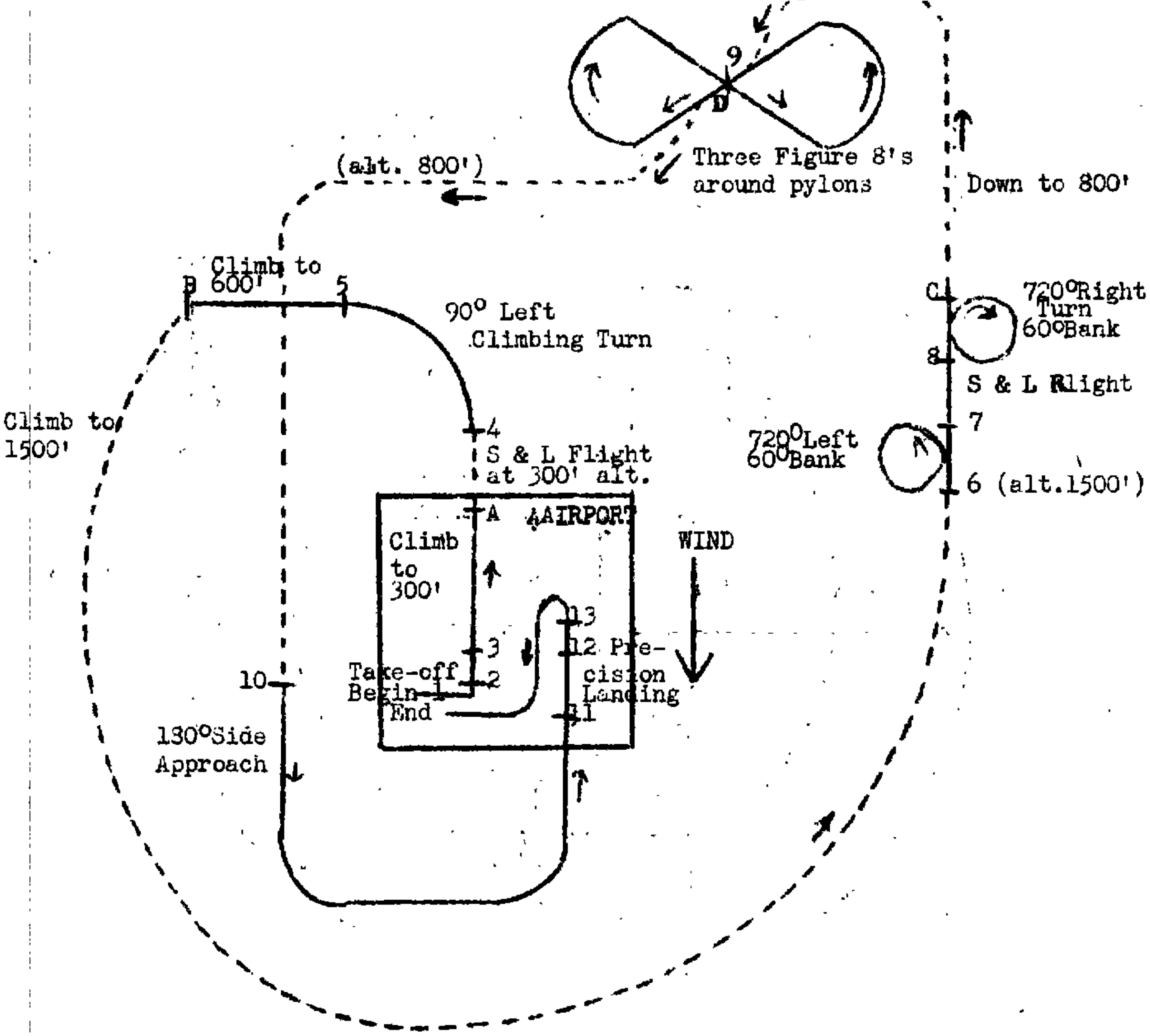
Note: The transition maneuvers are shown with dotted lines.

Prepared by: Morris S. Viteles
Albert S. Thompson
With the assistance of: Richard Bircher, director of flight instruction.
Date: April 1, 1940.

EXHIBIT 6

DIAGRAM OF STANDARD FLIGHT C1

(For the S. Davis Wilson Airport, Phila., Pa.)



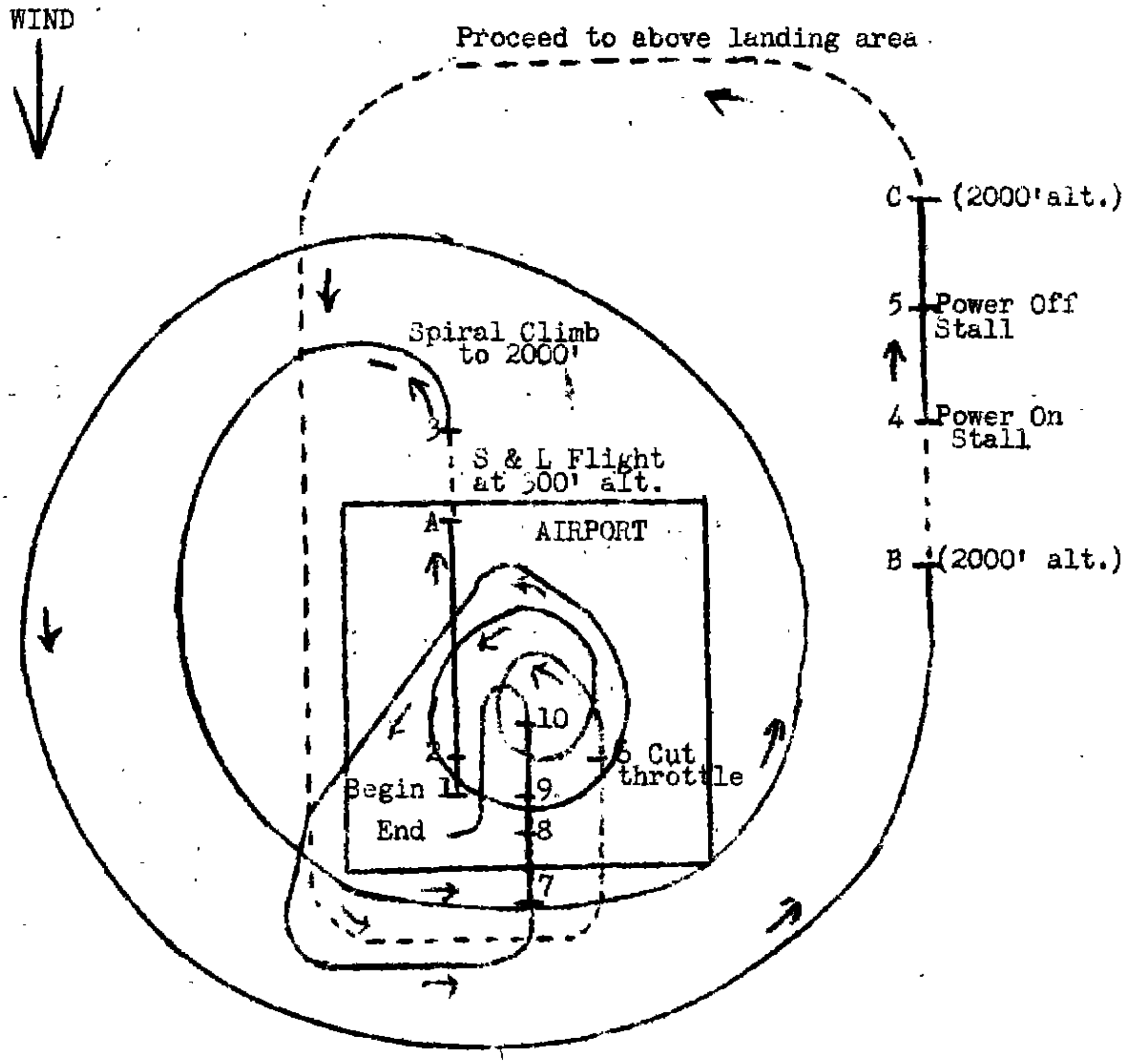
Note: The transition maneuvers are shown with dotted lines.

Prepared by: Morris S. Viteles
Albert S. Thompson
With the assistance of: Richard Bircher, director of flight instruction.
Date: April 1, 1940.

EXHIBIT 7

DIAGRAM OF STANDARD FLIGHT C2

(For the S. Davis Wilson Airport, Phila., Pa.)



Note: The transition maneuvers are shown with dotted lines.

Prepared by: Morris S. Viteles
Albert S. Thompson
With the assistance of: Richard Bircher, director of flight instruction.
Date: [illegible] 1, 1940.

II. Development of Technical Procedures.

Another important outcome of the University of Pennsylvania Research Project was the adaptation of the techniques of motion photography and of micromotion analysis to the study of movements used in the control of an airplane. For example, the development of methods for computing control-movement ratios, described in Part I of this report, sets the ground-work for further productive research in objectively studying movements employed by pilots in controlling the plane during flight.

III. Findings on the Flying Habits of "Superior" and "Inferior" Pilots.

The development of techniques was paralleled by the assembly of considerable data obtained through the application of these techniques. From analysis of these data it is possible to submit certain tentative findings with respect to the patterns of response characterizing "superior" and "inferior" pilots, respectively. These findings must be considered as highly tentative in character since:-

(1) The number of subjects was small.

(2) The number of observations on each subject was limited. This applies particularly to the photographs of control movements, since only one photographic record was made of each of the 6 maneuvers included in the Main Experiment. It is quite possible that a single flight does not give an adequate sampling of the pilot's general flying habits. As a matter of fact, an examination of the 38 graphs of control movements prepared in the course of this study revealed instances where the "superior" pilot[16] produced a record which indicated inferior performance, and instances where an "inferior" pilot's record showed performance superior to his general level of response. Such instances tend to cloud the general trend revealed by a comparison of the two groups.

(3) The classification of pilots into "superior" and "inferior" groups was made "subjectively" on the basis of direct observation. Although this classification was independently confirmed by the local flight director of the Civilian Pilot Training program, such a classification is not completely acceptable as a device for classifying pilots with respect to proficiency in piloting a plane in the experimental study of the nature of this skill.[17]

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[16] Classified on the basis of an evaluation of general flying habits observed during flight, as described on pages 3 to 6 and page10 .

[17] It is to be noted that in the continuation of the University of Pennsylvania Research Project it is planned to use more objective methods for classifying pilots as to proficiency in piloting a plane. For this purpose use will be made of (a) either the Kellogg Response Recorder or the Friez Control Cable Recorded to give records of control-cable movements, and (b) either the Redhed Ride Recorder or the Friez Flight Analyzer to provide the record of plane attitude coincident with the wheel movements recorded photographically.

During the present experiment an effort was made to procure objective measurements of plane performance by plotting Turn Indicator readings. The nature of such records is illustrated in Graphs VIIa and VIIb which show the changes in the position of the Turn Indicator needle and concurrent wheel and wheel-column movements during Straight and Level Flight by a "superior" pilot of the main experimental group and by a student pilot with approximately 1-1/2 hours of instruction. Turn Indicator readings were obtained by assigning a numerical value to the Turn Indicator needle position in successive frames. These numerical values range from L 5 through 0 to R 5, the far, near and center marks on the Turn

(4) Since various techniques were employed in various stages of the research, there appeared certain discrepancies in the findings which served to detract from the clear-cut nature of the findings.

With the reservations noted above it is possible to submit the following highly tentative findings with respect to the body and limb positions and movements employed by "superior" and "inferior" pilots, respectively, in controlling a plane. The experimental procedure from which the finding is derived is indicated in each case. In addition, illustrative material in the form of photographs, graphs, and tables is provided to indicate the nature of the data obtained, and how these data were treated to arrive at these general findings.

A. Findings Based on Direct Observation during Flight and Confirmed by Slow Motion Projection of Photographs.

1. Body and Limb Positions.

a. General Posture:[18]

(1) Both "superior" and "inferior" pilots tended to sit erect during flight.

(2) Both groups tended to place the heels on the floor and the ball of the foot across the rudder bar.

b. Location of Hand on Wheel:

Both "superior" and "inferior" pilots, when seated in the plane and prepared for flight, placed the hand at or slightly to the left of the top-center of the wheel-rim with the thumb extending slightly to the right of center, as illustrated on photograph A, Exhibit 8.

c. Wheel Grasp:

Both groups grasped the wheel in much the same way, as illustrated in photograph A, Exhibit 8. This basic or standard wheel grasp may be described as follows:-

(1) The anterior portion of the palm of the left hand is placed on the top rim of the wheel.

(2) The rim is encircled rather loosely by the four fingers, with the knuckles facing the instrument board.

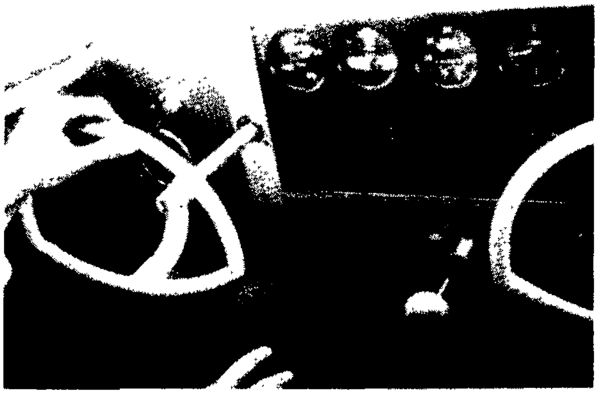
Indicator having the values of 5, 2, and 0, respectively. "L" refers to a position to the left of the center mark and "R" to a position to the right of the center mark.

If difficulties are experienced with the instruments to be used in recording flight attitude, the investigator may continue further with the use of such plottings of Turn Indicator, supplemented by a similar graphic treatment of Bank Indicator readings, as a basis for passing judgment on flight attitude during maneuvers and for classifying pilots for over-all proficiency in handling the plane.

[18] Not observable during slow-motion projection of photographs because of the limited field of the camera.

EXHIBIT 8

PHOTOGRAPH A



Basic Wheel Grasp

PHOTOGRAPH B

Wheel Grasp During Take-off

PHOTOGRAPH C

Throttle Grasp

(3) The fore-finger and thumb are extended toward the right along the face of the wheel rim to provide what might be called a "finger-tip" grasp.

In general, this wheel grasp is essentially that obtained by placing the hand upon the wheel in a relaxed manner with the arm extending obliquely downward and toward the left.

d. Wheel Grasp during Take-Off:

Both "superior" and "inferior" pilots tended to use a modification of the standard wheel grasp during the Take-Off maneuver. In this the wrist was dropped slightly, bringing the hand into a more nearly vertical position; the rim was more tightly encircled by the four fingers with the knuckles extending approximately along the top of the rim of the wheel, and the thumb was pressed more firmly against the face of the wheel rim (photograph B, Exhibit 8); This tended to give a firmer grasp and a greater palm surface along the front rim of the wheel to provide greater pressure in pushing the wheel forward for lowering the elevators during the Take-Off run.

e. Throttle Grasp:

Both "superior" and "inferior" pilots tended to grasp the throttle with the ball in the palm of the right hand and the first finger placed lengthwise along the top of the plunger in the direction of the throttle lock, as illustrated in Photograph C, Exhibit 8.

2. Body and Limb Movements during Flight.

a. General Body and Head Movements:

Both "superior" and "inferior" pilots exhibited little body movement during flight except for a slight sway toward the direction of the turn and occasional head movements to observe traffic.[19]

b. (1) The "superior" pilots tended to use wrist and finger and slight arm movements in preference to full arm movements in making slight wheel movements for aileron adjustment. In contrast, "inferior" pilots tended more frequently to use movements of the entire arm for this purpose.

(2) The "superior" pilots tended to use finger, thumb, and wrist movements for pushing or pulling the wheel-column in making slight elevator adjustments, while the "inferior" pilots tended to use the whole arm, even in the case where very small adjustments are required.

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[19] Not observable during slow motion projection of photographs because of the limited field of the camera.

[20] These were observed only in part by the method of slow-motion projection of photographs since the camera field did not include the entire arm. However, the photographs made it possible to observe slight finger movements in greater detail than was possible by the method of direct observation.

B. Findings Obtained from the Analysis of Graphic Records of Wheel and Wheel-Column Movements.

1. Statistical Methods for Treating Quantitative Data. As indicated in preceding **pages** (10) to (16), graphs obtained by plotting successive wheel and wheel-column positions during frame-by-frame projection of motion photograph were studied: (a) by visual inspection; (b) by the application of simple, quantitative techniques; and (c) through the computation of control-movement ratios. Findings obtained through the application of these procedures are presented below, classified with respect to the 6 maneuvers employed in the Main Experiment (page 10).

The t-test:- These findings were based, in part, upon the comparison of mean scores of "superior" and "inferior" pilots. In preparing such comparisons, use was made of Fisher's t-test[21] for determining the significance of the difference between the means of small samples. The t-test essentially provides for small samples and statistic analogous to the "critical ratio" commonly used to describe the reliability of a difference between the means of larger, presumably normal sampling distributions.

P-Values:- For small samples the probability that two samples differ significantly in their means, or, more exactly, the probability that the two samples were drawn at random from identical normal populations (with the same mean and the same standard deviation) is expressed in a P-value to be found in a table, prepared by Fisher, which gives P-values for t's obtained by the treatment of data referring to differing numbers of cases.[22]

In Tables I to VI (pages 31 to 36) are found the range of control-movement ratios, midscores and mean scores for "superior" and "inferior" pilots, respectively, classified with respect to maneuvers. In addition, the difference between the mean scores of "superior" and "inferior" pilots is given for each of the control-movement ratios, and the significance of this difference expressed in terms of P-value.

Levels of Significance:- For the interpretation of the P-values it should be recalled that a P-value $<.01$ (less than .01) means that the probability that an observed difference is due to "chance" is only 1 in 100. In other words, a P-value $<.01$ means that the observed difference will be obtained from random samplings of essentially identical populations (i.e. with the same degree of proficiency in piloting) fewer than 10 times in every 1000 drawings of random samples (1 in 100). Where P-value is $<.05 > .01$ (less than .05 greater than .01) the probability is from 1 to approximately 5 in 100 that the observed difference between the means of

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[21] See. Fisher, R.A. Statistical Methods for Research Workers, Fifth Edition, Edinburgh; Oliver & Boyd, 1934, pp. 120-121..
The formula is

$$t = \frac{\bar{x} - \bar{x}'}{s} \sqrt{\frac{(n_1 + 1)\ (n_2 + 1)}{n_1 + n_2 + 2}}$$

in which

$$s^2 = \frac{1}{n_1 + n_2} \left\{ S(x-\bar{x})^2 + S(x' - \bar{x}')^2 \right\}$$

$$\bar{x} = \frac{1}{n_1 + 1} S(x), \quad \bar{x}' = \frac{1}{n_2 + 1} S(x'),$$

$$n = n_1 + n_2$$

[22] Ibid., p. 158.

wo groups is due to chance, or, in other words, that the two samplings represent essentially the same or identical populations.

For the purposes of this study, the P-values were interpreted as follows: (1) it was assumed that with a P-value greater than .05 there was essentially no true difference in movement pattern (as represented by control movement ratios) between "superior" and "inferior" pilots, since such a P-value means that an observed difference will appear in more than 5 cases out of every 100 when random samplings of pilots from the same general population are compared; (2) it was assumed that P-values between .05 and .01 gave reasonable grounds for the belief that the difference in means between the two groups was not due primarily to chance; and (3) it was assumed that with a P-value of .01 or less there was great justification for the belief that the two groups differed significantly since such a P-value indicates that the observed difference will occur by chance in only one or less than one case in 100.

In addition to t-scores and P-values, other types of statistical comparisons were employed in arriving at the findings presented below. In general, there is found here an indication of the manner in which data can be treated in the larger-scale investigation to be undertaken during the forthcoming research period.

2. Differential Pilot Responses in 6 Maneuvers.

TAKE-OFF

a. From visual inspection of graphs. (See Graphs Ia and Ib)

(1) With one exception, "superior" pilots started the Take-Off run with the wheel-column back of the neutral point. The column was held in this position for approximately 3 seconds of the Take-Off run before being pushed forward to lower the elevators. This pattern of response was exhibited by only one of the "inferior" pilots. In addition, one "inferior" pilot (Graph Ib) actually began the Take-Off run with the wheel-column forward of neutral and held it there, with considerable fluctuations of position, during most of the Take-Off run.

(2) Both "superior" and "inferior" pilots tended to pull the wheel-column back sharply and smoothly during the few moments previous to leaving the ground. In contrast, the "inferior" pilots pulled the wheel-column back irregularly with occasional jerky and regressive movements. As a matter of fact, while all "inferior" pilots made such regressive wheel-column movements during the 3 seconds preceding the movement of leaving the ground, only one of the "superior" pilots changed the direction of wheel-column movement during this period.

(3) All "superior" pilots pushed the wheel-column forward slightly, in order to level off, during the second following the moment of leaving the ground. Only one of the "inferior" pilots made this adjustment within a similar period (Graph Ib).

b. From treatment of control-movement ratios. (See Table I.)

(1) "Inferior" pilots exhibited a greater amount of wheel movement during this maneuver, as indicated by the large, positive difference between the means of Index 1 (Table I). The P-value for the difference between the means (<.01) is highly significant.

It is also to be noted that there was no overlap between ranges of scores for "superior" and "inferior" pilots respectively. It is perhaps also significant to find that the index score of the only student pilot in the investigation is the maximum score (representing greatest amount of movement) for the entire group.[23]

(2) "Inferior" pilots also exhibited a greater amount of wheel-column movement during Take-Off. Although the difference between the means of the two groups for Index 1, Wheel-Column movement, (P-value <.10> .05) did not reach the level of significance set as a criterion in this study, it should be noted that there was practically no overlap between the scores of the two groups. In this case, the student's score was also at the extreme (maximum) score.

(3) "Inferior" pilots kept the wheel in motion during a greater percentage of the total time of the maneuver than did the "superior" pilots as indicated by a difference of 14.5 between the means of Index 2, wheel movement. A P-value of <.05 > .02 indicated that this difference was statistically significant. In addition, there was no overlap between the range of scores of "inferior" and "superior" pilots. Index 2 for the student was the maximum score for the total group.

STRAIGHT AND LEVEL FLIGHT

a. From visual inspection of graphs. (See graphs IIa and IIb.)

No differences between "superior" and "inferior" pilots appeared when graphic records were inspected visually and the data submitted to simple quantitative treatment.

b. From treatment of control movement ratios. (See Table II.)

None of the P-values for differences in mean index scores for this maneuver fell below .05, the desired level of significance. However, it seems desirable to call attention to the following findings:[24]

(1) "Inferior" pilots kept the wheel in motion during a smaller percentage of the total time of the maneuver (Index 2, wheel) than did "superior" pilots. Although the P-value (<.10 >.05), was not within the same significance, the range of scores of the two groups did not overlap and the student's score was the minimum score of the total group. For example, in Graph IIa, Index 2 for the "superior" pilot proved to be 47.5, while the "inferior" pilot obtained a corresponding score of 28.3 (Graph IIb).

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[23] Of the total of 60 indices computed (5 ratios of wheel and wheel-movement separately for each of 6 maneuvers) the student's index score is found to be either the maximum or minimum score for the combined groups in 26 of the cases. In 25 of the 26 instances, his score is at that end of the range in which the scores of the "inferior" pilots fall. In general, in about 40% of the indices computed the student obtains the "poorest" score.
This analysis is presented as being of interest in view of the proposed extension of this study in which students are to be observed during the entire period of instruction, and their responses studied both at various stages of instruction and in comparison with those of flight instructors, or other highly experienced pilots.

[24] These findings are particularly interesting in that Straight and Level Flight was the only maneuver of the six maneuvers studied in which the activity of the "superior" pilots tended to be greater than that of "inferior" pilots. It may also be noted that none of the differences in means or medians given in Table II was positive in direction.

(2) "Inferior" pilots made a smaller total number of wheel-column movements (Index 3, wheel-column - Table II) during straight and level flight than did "superior" pilots. Here again, the P-value of the difference between the means, ($<.10 > .05$) was beyond the level of significance, but there was also no overlap in Index 3, wheel-column scores, between the two groups, and the student obtained the minimum score of the total group.

(3) "Inferior" pilots made fewer regressive wheel-column movements (index 4, wheel-column, Table II) during straight and level flight than did "superior" pilots. The P-value was again beyond the accepted level of significance, $<.1 > .05$, but there was no overlap in the index scores between the two groups, and the student obtained the minimum score of the total group.

90° MEDIUM TURNS

a. From visual inspection of graphs. (See Graphs IIIa, b and IVa, b.)

Inspection of the records of this maneuver revealed no consistent patterns of movement exhibited either by both groups or by the "superior" and "inferior" groups, respectively.[25]

b. From simple quantitative treatment of graphs.

No characteristics differentiating "superior" and "inferior" pilots were noted by this method.

c. From treatment of control movement ratios. (See Tables III & IV.)

An examination of P-values, range, etc., showed no differentiating characteristics between "superior" and "inferior" pilots in terms of control-movement ratios.

360° LEFT POWER TURN

a. From visual inspection of graphs. (See Graphs Va and Vb.)

All but one of the pilots, including both "superior" and "inferior" pilots, exhibited the following pattern of control movement during the entry into the turn:

(1) The wheel-column was pulled back slightly while the wheel was being turned to the left to make aileron adjustments for banking the plane.

(2) The extent of this backward movement of the wheel-column was increased soon after the wheel reached the maximum position to the left, and continued as the wheel was returned toward the right with a view to maintaining the bank of the plane. This pattern of movement is seen quite clearly in Graph Va.

b. From quantitative indices of graphs. (See Table V.)

"Inferior" pilots kept the wheel in motion during a greater percentage of the total time than did "superior" pilots. The P-value $<.01$ for the difference

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[25] Although the 90° Medium Left Turn graphs seemed to show a tendency for most of the subjects to maintain wheel movement towards the right during the turn to hold the bank, even this tendency was clouded by considerable fluctuation of movement in the case of a few of the subjects and was not discernible in the graphs of the 90° Medium Right Turn.

between the means of Index 2 for the two groups is highly significant.

LANDING

a. From visual inspection of graphs. (See Graphs VIa and VIb.)

(1) Both "superior" and "inferior" pilots tended to pull the wheel-column to the maximum back position slightly prior to the moment of landing.

(2) "Superior" pilots tended to hold the wheel-column more firmly in the back position at the moment of landing and during the first few seconds of the landing run than did "inferior" pilots. This is displayed in the fluctuation of the wheel-column positions during this portion of the maneuver in Graph VIb as compared with Graph VIa.

(3) "Superior" pilots exhibited a greater total amount of wheel movement immediately preceding the moment of landing than did "inferior" pilots.

b. Treatment of control movement ratios. (See Table VI.)

Visual inspection showed that "superior" pilots exhibited a greater total amount of wheel movement immediately preceding the moment of landing than did "inferior" pilots. This observation was checked quantitatively by computing an Index 1 applying to the portion of the graph representing the 4 seconds of wheel activity preceding the moment of landing. The difference in mean scores between "superior" and "inferior" pilots for this partial Index 1 proved to be .383. The P-value for this difference ($<.05>.02$) is statistically significant. In addition, the ranges of obtained ratios for the "superior" and "inferior" pilots did not overlap and the score of the student pilot was the minimum for the total group.

C. A Note on Discrepancies.

There are presented above only those findings for which no contradictory evidence appeared when the results obtained by the various experimental procedures were compared. However, it is interesting to note that there were relatively few instances of striking discrepancies, and that most of the latter occurred when the results of direct observation and slow-motion projection of photographs were compared. These may have resulted, in part, from the facts that (a) the camera field of the photograph did not include the trunk and feet of the subject, and (b) the photographs provide opportunities for more detailed observation of slight finger and thumb movements, which cannot be observed during direct observation flights by the investigator, and (c) the photographic records were of single, short maneuvers. A few instances of such discrepancies may be noted for illustrative purposes:-

1. According to direct observation during flight, the "superior" subjects occasionally released the throttle and used the right hand to aid in making wheel and wheel-column movements during the more difficult maneuvers, such as Take-Off, 720° Power Turn, Stalls and Recovery, Figure 8's, and Landing (Appendix A). This differentiating characteristic did not appear during slow-motion projection of the photographs. In the latter, it appeared that only two subjects, one in the "superior" group and one in the "inferior" group, used both hands on the wheel. These pilots used both hands on the wheel for nearly all the maneuvers photographed.

2. According to direct observation during flight, the "superior" subjects

TABLE I - TAKE OFF

Control Movement Ratios

Comparison of Ranges, Midscores and Means of "Superior" and "Inferior" Pilots*

INDEX --		Index 1 Total Amount of Control Movement		Index 2 Percent of Total Time in Motion		Index 3 Number of Control Movements		Index 4 Changes in Direction of Control Movements		Index 5 Discontinuity of Control Movements	
		Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column
I-RANGE											
Both Groups	Max.	1.414	1.444	72.8	66.0	.403	.409	.302	.297	.105	.147
	Min.	1.049	1.209	47.8	39.9	.309	.209	.239	.142	.070	.067
"Superior" Pilots	Max.	1.148	1.289	51.0	55.7	.403	.409	.302	.289	.101	.147
	Min.	1.049	1.209	47.8	39.9	.309	.209	.239	.142	.070	.067
"Inferior" Pilots	Max.	1.414	1.444	72.8	66.0	.401	.401	.299	.297	.105	.136
	Min.	1.320	1.287	59.5	51.0	.365	.320	.276	.197	.089	.104
II-MIDSCORES											
"Superior" Pilots		1.074	1.218	50.7	54.2	.372	.309	.284	.162	.088	.120
"Inferior" Pilots		1.354	1.327	60.6	53.9	.383	.333	.278	.202	.102	.108
Difference		.280	.109	9.9	-0.3	.011	.024	-.006	.040	.014	-.012
III-MEAN SCORES											
"Superior" Pilots		1.090	1.239	49.8	49.9	.275	.198	.361	.309	.086	.111
"Inferior" Pilots		1.363	1.353	64.3	57.0	.284	.252	.383	.351	.099	.116
Difference		.273	.116	14.5	7.1	.009	.034	.022	.042	.013	.005
P-Values		P<.01	P<.1>06	P<.05>.02	P<.4>.3	P<.5>.4	P<.6>.5	P<.7>.6	P<.6>.5	P<.3>.2	P<.9>.8

(*) Since the midscore, or mean, index of "superior" pilots is in each case subtracted from that of the "inferior" pilots, a difference preceded by a minus sign indicates a higher midscore, or mean, index for the "superior" pilots.

TABLE II - STRAIGHT & LEVEL FLIGHT

Control Movement Ratios

Comparison of Ranges, Midscores and Means of "Superior" and "Inferior" Pilots*

INDEX --		Index 1 Total Amount of Control Movement		Index 2 Percent of Total Time in Motion		Index 3 Number of Control Movements		Index 4 Changes in Direction of Control Movements		Index 5 Discontinuity of Control Movements	
		Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column
I-RANGE											
Both Groups-	Max.	1.167	1.067	53.3	31.7	.408	.308	.275	.267	.167	.059
	Min.	1.043	1.008	28.3	6.7	.183	.067	.108	.067	.056	.000
"Superior" Pilots	Max.	1.167	1.067	53.3	31.7	.408	.308	.275	.267	.167	.059
	Min.	1.083	1.025	43.3	10.0	.258	.100	.158	.092	.100	.008
"Inferior" Pilots	Max.	1.076	1.025	43.3	10.8	.281	.100	.225	.083	.092	.017
	Min.	1.042	1.008	28.3	6.7	.183	.067	.108	.067	.056	.000
II-MIDSCORES											
"Superior" Pilots		1.092	1.033	47.5	23.3	.350	.242	.183	.183	.133	.041
"Inferior" Pilots		1.059	1.017	34.2	7.5	.275	.067	.183	.067	.075	.000
Difference		-.033	-.016	-13.3	-15.8	-.075	-.175	.000	-.116	-.058	-.041
III-MEAN SCORES											
"Superior" Pilots		1.114	1.042	48.0	21.7	.339	.217	.205	.181	.133	.036
"Inferior" Pilots		.064	1.014	35.3	8.3	.246	.078	.172	.072	.074	.006
Difference		-.050	-.028	-12.7	-13.4	-.093	-.139	-.033	-.109	-.059	-.030
P-Values		$P<.2>.1$	$P<.2>.1$	$P<.1>.05$	$P<.7>.6$	$P<.3>.2$	$P<.1>.05$	$P<.6>5$	$P<.1>05$	$P<.1>.05$	$P<.2>.1$

(*) Since the midscore, or mean, index of "superior" pilots is in each case subtracted from that of the "inferior" pilots, a difference preceded by a minus sign indicates a higher midscore, or mean, index for the "superior" pilots.

TABLE III - 90° LEFT TURN

Control Movement Ratios

Comparison of Ranges, Midscores and Means of "Superior" and "Inferior" Pilots*

INDEX --		Index 1 Total Amount of Control Movement		Index 2 Percent of Total Time in Motion		Index 3 Number of Control Movements		Index 4 Changes in Direction of Control Movements		Index 5 Discontinuity of Control Movements	
		Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column
I-RANGE											
Both Groups-	Max.	1.218	1.076	55.8	17.1	.298	.160	.204	.126	.124	.053
	Min.	1.043	1.015	29.4	5.9	.176	.044	.096	.022	.063	.000
"Superior" Pilots	Max.	1.081	1.076	45.2	17.1	.276	.159	.178	.114	.098	.053
	Min.	1.043	1.015	29.4	5.9	.176	.044	.096	.022	.063	.022
"Inferior" Pilots	Max.	1.218	1.025	55.8	16.5	.298	.160	.204	.126	.124	.034
	Min.	1.063	1.019	36.4	6.8	.199	.063	.136	.057	.063	.000
II-MIDSCORES											
"Superior" Pilots		1.069	1.024	35.7	12.5	.223	.133	.154	.088	.088	.041
"Inferior" Pilots		1.093	1.023	45.3	11.2	.272	.106	.174	.106	.068	.006
Difference		.024	-.001	9.6	-1.3	.049	-.027	.020	.018	-.020	-.035
III-MEAN SCORES											
"Superior" Pilots		1.065	1.035	36.5	12.0	.224	.117	.140	.078	.084	.039
"Inferior" Pilots		1.125	1.022	45.8	11.5	.256	.110	.171	.096	.085	.013
Difference		.060	-.013	9.3	-0.5	.032	-.007	.031	.018	.001	-.026
P-Values		$P<.3>.2$	$P<.5>.4$	$P<.2>.1$	$P<.9>.8$	$P<.5>.4$	$P<.9>.8$	$P<.3>.2$	$P<.6>.5$	$P>.9$	$P<.1>.05$

(*) Since the midscore, or mean, index of "superior" pilots is in each case subtracted from that of the "inferior" pilots, a difference preceded by a minus sign indicates a higher midscore, or mean, index for the "superior" pilots.

TABLE IV - 90° RIGHT TURN

Control Movement Ratios

Comparison of Ranges, Midscores and Means of "Superior" and "Inferior" Pilots*

INDEX --		Index 1 Total Amount of Control Movement		Index 2 Percent of Total Time in Motion		Index 3 Number of Control Movements		Index 4 Changes in Direction of Control Movements		Index 5 Discontinuity of Control Movements	
		Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel-	Wheel-Column	Wheel	Wheel-Column
I-RANGE											
Both Groups	Max.	1.192	1.086	51.0	20.6	.262	.168	.192	.135	.081	.058
	Min.	1.048	1.013	30.1	9.3	.161	.083	.102	.048	.052	.023
"Superior" Pilots	Max.	1.192	1.027	51.0	20.6	.245	.165	.192	.113	.069	.058
	Min.	1.048	1.013	30.1	9.3	.161	.083	.102	.048	.052	.023
"Inferior" Pilots	Max.	1.133	1.086	46.7	17.3	.262	.168	.181	.135	.081	.033
	Min.	1.081	1.028	41.1	12.9	.232	.110	.168	.081	.064	.029
II-MIDSCORES											
"Superior" Pilots		1.084	1.021	36.4	14.2	.192	.116	.132	.083	.056	.031
"Inferior" Pilots		1.107	1.057	43.9	15.1	.247	.139	.175	.108	.073	.031
Difference		.023	.036	7.5	0.9	.055	.023	.043	.025	.017	.000
III-MEAN SCORES											
"Superior" Pilots		1.102	1.021	38.5	14.6	.198	.120	.139	.082	.058	.036
"Inferior" Pilots		1.107	1.057	43.9	15.1	.247	.139	.175	.108	.073	.031
Difference		.005	.036	5.4	0.5	.049	.019	.036	.026	.015	-.005
P-Values		P>.9	P<.2>.1	P<.6>.5	P>.9	P<.2>.1	P<.7>.6	P<.3>.2	P<.5>.4	P<.2>.1	P<.8>.7

(*) Since the midscore, or mean, index of "superior" pilots is in each case subtracted from that of the "inferior" pilots, a difference preceded by a minus sign indicates a higher midscore, or mean, index for the "superior" pilots.

TABLE V - 360° LEFT POWER TURN

Control Movement Ratios

Comparison of Ranges, Midscores and Means of "Superior" and "Inferior" Pilots*

INDEX --		Index 1 Total Amount of Control Movement		Index 2 Percent of Total Time in Motion		Index 3 Number of Control Movements		Index 4 Changes in Direction of Control Movements		Index 5 Discontinuity of Control Movements	
		Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column
I-RANGE											
Both Groups	Max.	1.697	1.132	72.4	40.4	.293	.303	.237	.183	.091	.137
	Min.	1.084	1.049	40.1	22.2	.255	.176	.179	.039	.026	.054
"Superior" Pilots	Max.	1.697	1.132	72.4	31.5	.270	.217	.237	.147	.091	.118
	Min.	1.084	1.049	40.1	22.2	.259	.184	.179	.066	.026	.054
"Inferior" Pilots	Max.	1.257	1.101	54.1	40.4	.293	.303	.202	.183	.091	.137
	Min.	1.137	1.054	47.2	24.5	.255	.176	.186	.039	.069	.120
II-MIDSCORES											
"Superior" Pilots		1.350	1.049	66.1	27.4	.264	.195	.194	.131	.008	.073
"Inferior" Pilots		1.197	1.078	50.7	33.0	.274	.240	.194	.111	.080	.129
Difference		.153	.029	-15.4	5.6	.010	.045	.000	-.020	.012	.056
III-MEAN SCORES											
"Superior" Pilots		1.369	1.071	61.2	27.1	.264	.198	.201	.119	.063	.079
"Inferior" Pilots		1.197	1.078	50.7	33.0	.274	.240	.194	.111	.080	.129
Difference		-.172	.007	-10.5	5.9	.010	.042	-.007	-.008	.017	.050
P-Values		P⟨.5⟩.4	P⟨.9⟩.8	P⟨.01	P⟨.5⟩.4	P⟨.5⟩.4	P⟨.4⟩.3	P⟨.8⟩.7	P⟨.9⟩.8	P⟨.5⟩.4	P⟨.1⟩.05

(*) Since the midscore, or mean, index of "superior" pilots is in each case subtracted from that of the "inferior" pilots, a difference preceded by a minus sign indicates a higher midscore, or mean, index for the "superior" pilots.

TABLE VI - LANDING

Control Movement Ratios

Comparison of Ranges, Midscores and Means of "Superior" and "Inferior" Pilots*

INDEX --		Index 1 Total Amount of Control Movement		Index 2 Percent of Total Time in Motion		Index 3 Number of Control Movements		Index 4 Changes in Direction of Control Movements		Index 5 Discontinuity of Control Movements	
		Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column	Wheel	Wheel-Column
I-RANGE											
Both Groups	Max.	1.650	1.450	76.3	56.3	.413	.342	.350	.225	.137	.160
	Min.	1.225	1.113	43.8	36.3	.179	.150	.100	.054	.054	.062
"Superior" Pilots	Max.	1.563	1.225	76.3	54.0	.290	.342	.211	.224	.118	.160
	Min.	1.288	1.113	46.4	36.3	.179	.150	.100	.054	.054	.062
"Inferior" Pilots	Max.	1.650	1.450	68.8	56.3	.413	.313	.350	.225	.137	.113
	Min.	1.225	1.163	43.8	46.3	.263	.175	.175	.088	.120	.063
II-MIDSCORES											
"Superior" Pilots		1.458	1.175	60.3	43.8	.207	.201	.166	.101	.058	.097
"Inferior" Pilots		1.313	1.338	58.8	52.5	.275	.288	.188	.200	.087	.087
Difference		-.145	.163	-1.5	8.7	.068	.087	.022	.099	.029	-.010
III-MEAN SCORES											
"Superior" Pilots		1.442	1.165	60.7	44.5	.221	.224	.161	.120	.060	.104
"Inferior" Pilots		1.396	1.317	57.1	51.7	.317	.259	.238	.171	.079	.088
Difference		-.046	.152	-3.6	7.2	.096	.035	.077	.051	.019	-.016
P-Values		P<.8>.7	P<.2>.1	P<.8>.7	P<.3>.2	P<.2>.1	P<.6>.5	P<.3>.2	P<.5>.4	P<.4>.3	P<.7>.6

(*) Since the midscore, or mean, index of "superior" pilots is in each case subtracted from that of the "inferior" pilots, a difference preceded by a minus sign indicates a higher midscere, or mean, index for the "superior" pilots.

made fewer and less extensive shifts of location of the left hand from its basic location at or slightly to the left of the top-center of the wheel. The photographs, on the other hand, showed that the "superior" subjects made more frequent shifts of location. The shifts, however, were slight and seemed to be due to greater use of the wrist and fingers for slight wheel movements providing aileron adjustment. Again it may be suggested that the slight shifts of location actually occurred during the direct observation flights but that intensive study of slow motion photographs was necessary for their observation.

IV. Introspective Reports on Learning to Pilot an Aeronca Chief Plane.

Immediately after each instruction period, beginning with the first dual flight and extending through the first solo flight, Albert S. Thompson, assistant investigator in the University of Pennsylvania Research Project, prepared an introspective report on his experiences during the instruction periods. In these day-to-day reports, illustrated in Exhibits 9 and 10, pages 38 - 39 and available in the files of the University of Pennsylvania Project, are found important observations with respect to student-instructor relationships, perceptual cues, the development of skill, and other matters which have a bearing on the progress of a student undergoing primary flight instruction.

Major observations and conclusions concerning training procedures reached as a result of introspection by the student pilot are briefly summarized below:[26]

A. Orientation to a New Situation.

1. The beginning student is faced with the problem of orienting himself to a new environment and of responding to new stimuli difficult of interpretation. This problem of "general orientation" involves the development of familiarity with the location and function of the controls and instruments of the plane, with the appearance of "surroundings" when viewed from above, with the appearance of the horizon, with the characteristics of the air currents, etc.

2. There seems reason to believe that "general orientation" is of primary importance for the initial flight and that the failure to devote a considerable portion of the first flight to such "general orientation", rather than to actual manipulation of the controls, retards the development of rapid and accurate adjustment to the new situation.

B. Recognition of Cues.

1. Another major problem centers around the recognition and interpretation of cues which provide information concerning the attitude and path of movement of the moving vehicle. The beginner must learn to locate visual reference points for straight and level flight, for various banks, and for climbing and gliding angles. Auditory cues, from the sound of the motor and air, must be observed. Other sense modalities -- cutaneous, kinaesthetic, static, organic -- are stimulated by movements of the plane and the controls during flight.

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[26] Such introspective reports by one student pilot should be confirmed by reports obtained from other equally well-trained observers before reliance can be placed upon them as a basis for the modification of training procedures or for setting up step-by-step training procedures. They are presented here, however, as an indication of the type of data which can be obtained through controlled introspection by competent observers, and to suggest the way in which such findings can be profitably applied in the constructive modification of training programs.

EXHIBIT 9

INTROSPECTIVE REPORTS ON LEARNING TO PILOT AN AERONCA CHIEF

SAMPLE RECORD

Fifth Instruction Flight.

Date: February 28, 1940
Time: 4:30 - 5:00
Log to Date: 2 hours

The session consisted of the following:

1. Taxi: down wind. I handled all the controls and the throttle. Taxied full length of field.
2. Take-off: I handled the throttle under specific instructions by Rice, who partially handled the controls.
3. The session was devoted largely to practice on rectangular course flying. An area about the size of four city blocks was selected with roads and railroads forming the boundaries of a square. Continuous practice was given in following this square -- about 5 times to the left and 3 times to the right.
4. Then the same course was followed using climbing and gliding turns -- twice.
5. A 360° approach to landing was taken on the return to the field.
6. Landing: Without telling me in advance, I was allowed to make a landing-- with the instructor giving specific instructions and partially handling controls.
7. Taxi: to original position near hangar.

Comments:

1. For the first time I handled the throttle during the entire session. In the preceding session, I had not used the throttle at all although I had during the 2nd and 3rd sessions.
2. Maneuvers stressed: Rectangular course with level, climbing, and gliding turns.
3. Correct gliding angle is determined largely through auditory cues -- a certain hum of the motor and whistling of the wind. A visual cue is the propeller which slows down until it presents a kind of stroboscopic appearance.
4. So far there has been no explanation as to how to judge one's approach in landing -- when to level off, etc.
5. This time I controlled the amount of bank during turns much better and there was less tendency to drop the nose. I still had difficulty judging the attitude of the plane during turns due to the "off-center" position of the pilot. In discussion with the instructor, he said that the point to the left of center which is slightly below the horizon during level flight should be kept at that level during left or right turns. (This supersedes and corrects what I had reported on February 26th.)

EXHIBIT 10

INTROSPECTIVE REPORTS ON LEARNING TO PILOT AN AERONCA CHIEF

SAMPLE RECORD

Fourteenth Instruction Flight.

Date: April 24, 1940
Time: 4:45 - 5:15
Log to date: 6½ hours

This session was devoted as before to take-offs and landings. Five flights around the field were made. Due to the direction of the wind, the take-offs and landings had to be made slightly cross-wind. All the landings were satisfactory and the first three exceptionally good; in the last two, however, the angle of glide before levelling off was a little too shallow, resulting in a slight "mushing" of the plane.

This session was interesting in its light upon the progress of learning landings. Previously, I had had difficulty in judging the correct time to level off and in pulling the wheel back sufficiently to make a 3-point landing. As noted before in the previous sessions, good landings were not obtained until the end of the instruction period. This time, however, possibly due to the rather long interval since the last instruction period, the bad habits had dropped out. The first three landings were characterized by a rather off-hand attitude toward the landing process, and by a feeling of confidence. During the first three landings, however, I began to notice that the cross-wind was causing a slight wind-drift. This made me conscious of a further complication and distracted my attention from the attitude of the plane and the approach of the plane toward the ground. As a result, the last two landings were poorer than the first three.

Another interesting observation was that I had reached the stage where I could be a little less careful in the actual maneuver at the moment. As a result of this, the instructor had to caution me concerning two possibly dangerous practices: 1st, giving full throttle to start the take-off run before entirely completing the observation turn, and 2nd, going too abruptly into the climbing turn after the original take-off climb. Another correction was for the tendency to wait too long during the take-off before raising the tail.

The cross-wind landing requires a slight lowering of the wing toward the wind in order to correct for drift. Drifting is easily observed by noting whether the plane is travelling in a straight line toward an object.

By this time the operations necessary for taxiing, for rudder control, for straight and level flight, for going into glides and medium turns, have become rather automatic. In the case of the turns, however, I am still consciously attempting to coordinate the aileron and rudder movements. Sometimes I forget to release pressure from the rudder after the turn has been started. On the whole, however, I seem to be coordinating the rudder and aileron fairly well. I also seem to be able to keep track of surrounding traffic fairly well, although I have not yet formed the habit of looking back to the field when making the first turn after the take-off climb. In the previous session the instructor had pointed out the desirability of such a habit.

2. According to observations appearing in the introspective reports, the recognition of and correct interpretation of these cues (many of them peculiar to the flying situation) could be facilitated by a greater emphasis upon directed, concentrated attention to these cues during demonstration of maneuvers. The development of the capacity to recognize and use cues should be facilitated by making organized instruction in these matters a definite instead of an incidental feature of the training program.

C. Development of Skills.

As the student proceeds through the instruction program, habits of manipulation of controls in co-ordinated patterns must be developed. Introspection by the assistant investigator suggests that the development of these habits is affected by the following factors:-

1. Regularity of Instruction Periods. It was noted that when the intervals between sessions were irregular or lengthy, the automaticity of control co-ordination, especially of aileron and rudder, tended to break down. Judgments necessary for estimating for gliding angle and approach to landing are also adversely affected.

2. Provisions for Practice and Review. In connection with the schedule followed in the practice and review of maneuvers, the following items appear to be of particular significance:-

a. Practice in take-offs and landings was highly concentrated, consisting of consecutive short flights around the field. The short time elapsing between take-off and landing in the individual flights produced two effects:-

(1) There was considerable tension throughout such instruction periods because insufficient time was available to "recover" from the excitement aroused by the performance of the difficult and relatively hazardous maneuvers of take-off and landing;

(2) Review of previously learned maneuvers was neglected.

b. Although practice on the more difficult maneuvers, such as 720° power turns, stalls, forced landings, etc., includes review of previously learned operations, such as co-ordination of controls, maintaining straight and level flight, coming out of the turn "on course", and maintaining correct gliding and climbing angle, such review was treated as a very incidental feature of instruction during the period devoted to the more complex maneuvers listed above.

c. Since the landing maneuver requires continuous judgment as to the length of the glide, the direction and velocity of the wind, and the moment for final leveling off, little conscious attention can be paid to the attitude of the plane. It would therefore seem that landings should not be undertaken by the student until adjustments for plane stability have become rather automatic.

D. Specific Difficulties Encountered.

Following are observations on several specific difficulties experienced during the flight instruction by the assistant responsible for the introspective reports. Confirmation by other such reports may be helpful in indicating areas requiring emphasis by instructors during training:-

1. Because of the existence of habits associated with the operation of an automobile, there is a tendency to use the wheel as a turning device. Special attention must be given to the elimination of this interference effect.

2. There is a persistent tendency to try to lengthen the glide by pulling back on the wheel. This, of course, has exactly the opposite effect. This tendency is one requiring serious consideration in the first stages of flight instruction.

3. There is a marked tendency for the inexperienced pilot to restrict attention to the controls and nose of the plane, preventing observation of surrounding traffic and path of movement of the plane. This tendency must likewise be counteracted through systematic instruction and directed practice in spreading attention over all features of the environment requiring attention during flight.

4. Difficulty in training to co-ordinate aileron and rudder adjustment in entering a turn is increased by two factors: (a) the slight lag in the response of the plane to changes in the control surfaces, and (b) the difference in extent of response of the plane to "apparently" equal movements of the two controls.

These characteristics of the response of the plane to the controls may explain why the beginning student tends to over-control, since the beginner is inclined to increase the extent of aileron and rudder control during the period of lag, resulting in over-banking and an irregular turn.

E. Practice Preceding the First Solo Flight.

As noted in the detailed introspections on the first solo flight, the difficulties of this flight were minimized by the practice flights taken immediately before the initial solo flight. The chief value of such practice lies in the opportunity for the student to acquire information as to wind conditions at the time of the solo flight, the correct path around the field, and the correct position for cutting throttle preparatory to the final approach for landing. To alleviate the excitement usually accompanying the first solo flight, it is suggested that the instructor direct the attention of the student to these points during practice flights immediately preceding the solo flight.

V. In Conclusion.

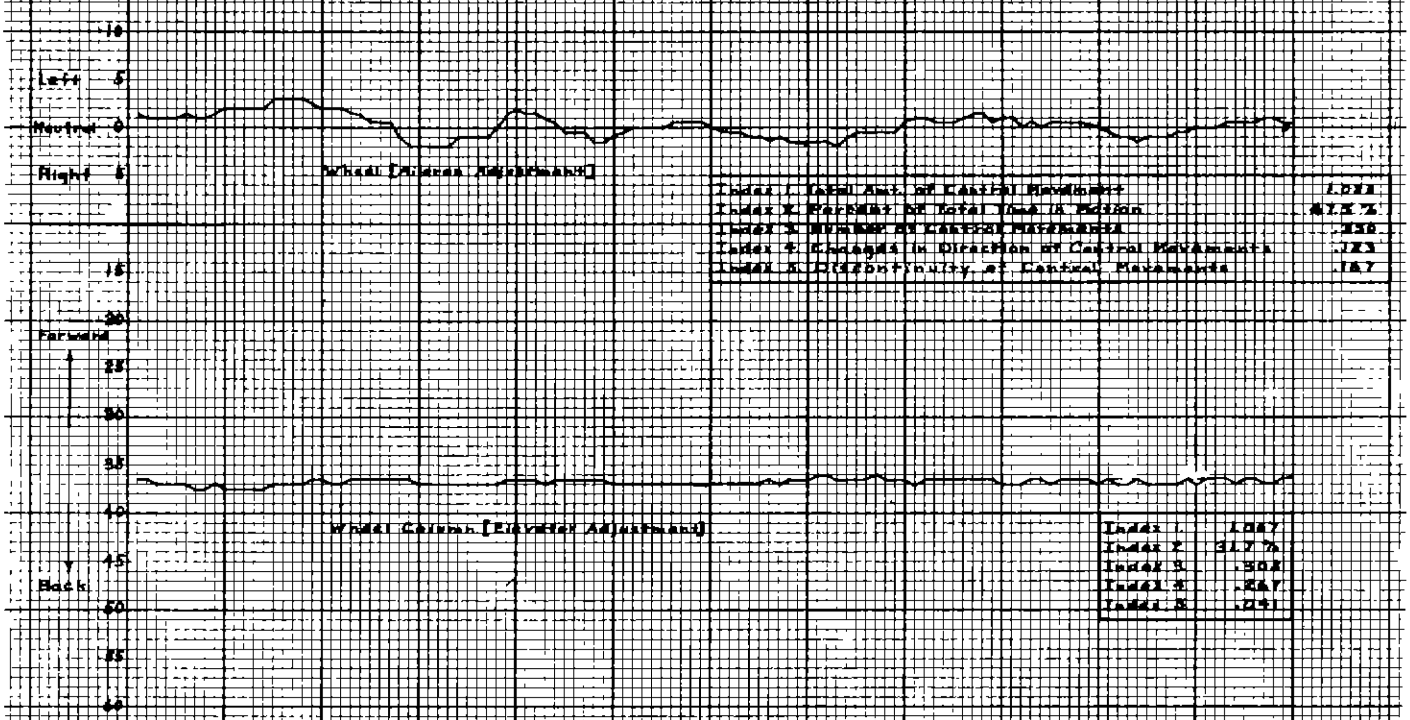
The study described in this report resulted in the development of standard flights for use in observing pilot performance and of techniques for the analysis of motion photographs taken during flight. Photographic records were found to yield important data concerning patterns of control movements and general flying habits of pilots when viewed during slow-motion projection and when studied during frame-by-frame projection. Tentative findings based on a study involving two small groups indicated areas in which "inferior" and "superior" pilots differed in characteristic habits of flight performance.

Further research will be devoted to an improvement of the standard flights and to an expansion and refinement of both "qualitative" and "quantitative" methods of analysis of photographic records of flight performance.

Part III

GRAPHS I to VII

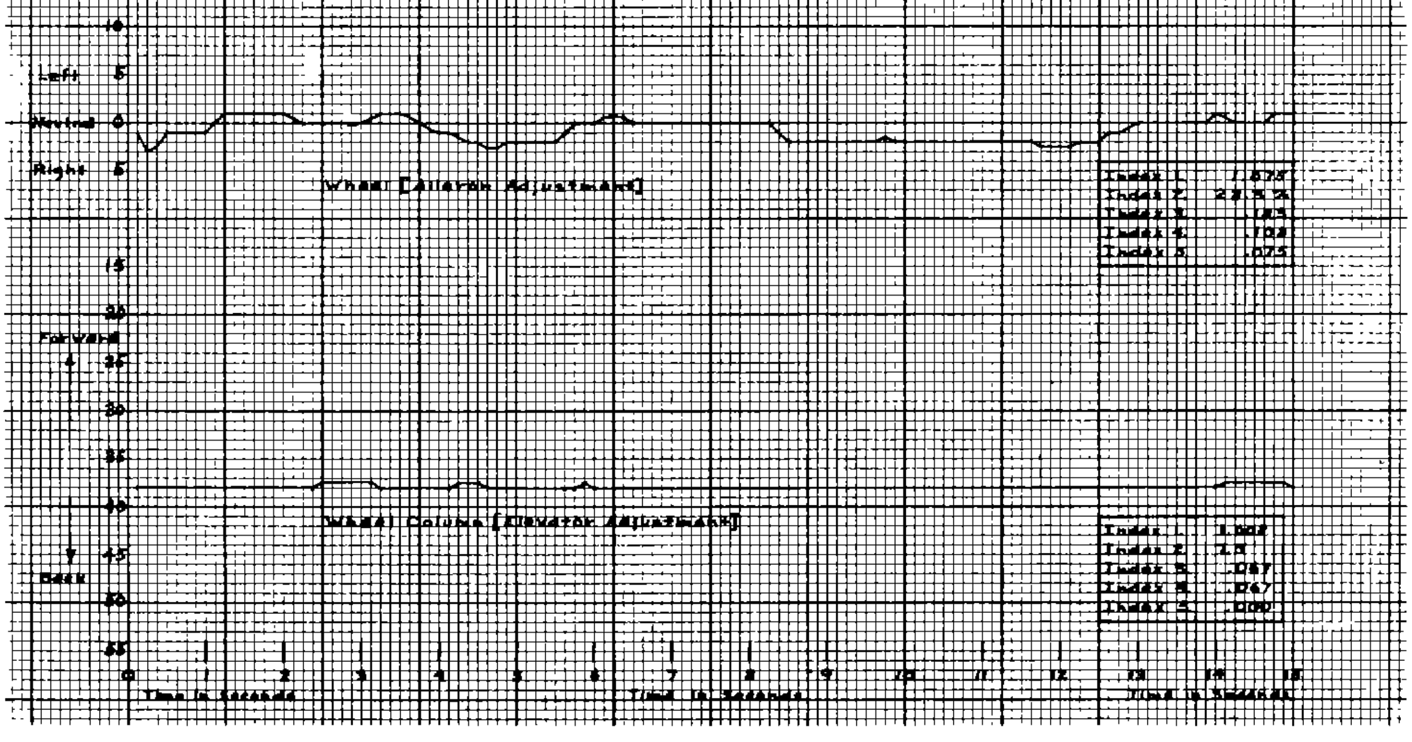
GRAPH IIa
STRAIGHT AND LEVEL FLIGHT
"Superior" Pilot



Index 1. Total Amt. of Control Movement	1.033
Index 2. Percent of Total Time in Motion	47.5 %
Index 3. Number of Control Movements	.250
Index 4. Changes in Direction of Control Movements	.123
Index 5. Discontinuity of Control Movements	.167

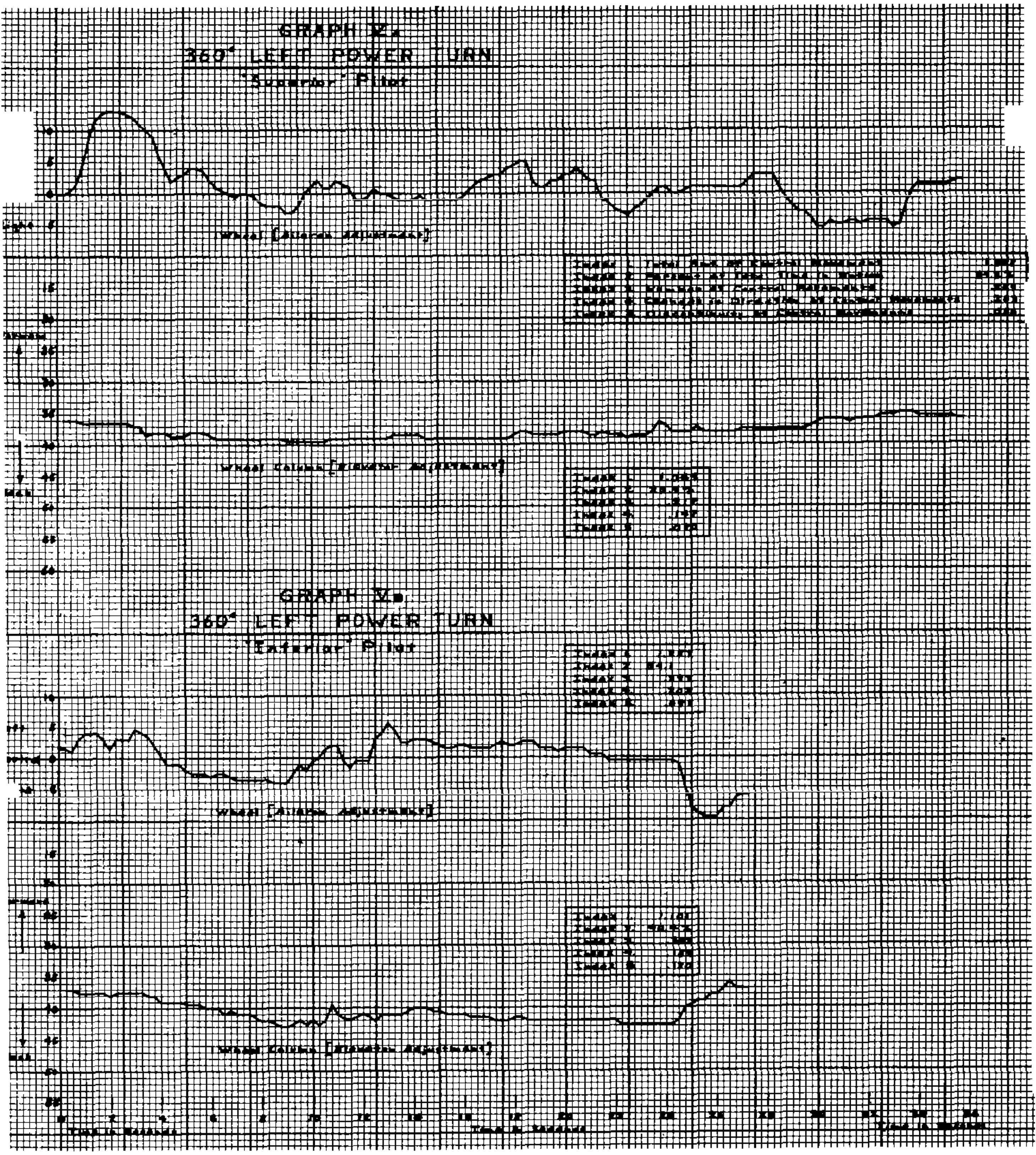
Index 1.	1.067
Index 2.	31.7 %
Index 3.	.508
Index 4.	.267
Index 5.	.041

GRAPH IIb
STRAIGHT AND LEVEL FLIGHT
"Inferior" Pilot



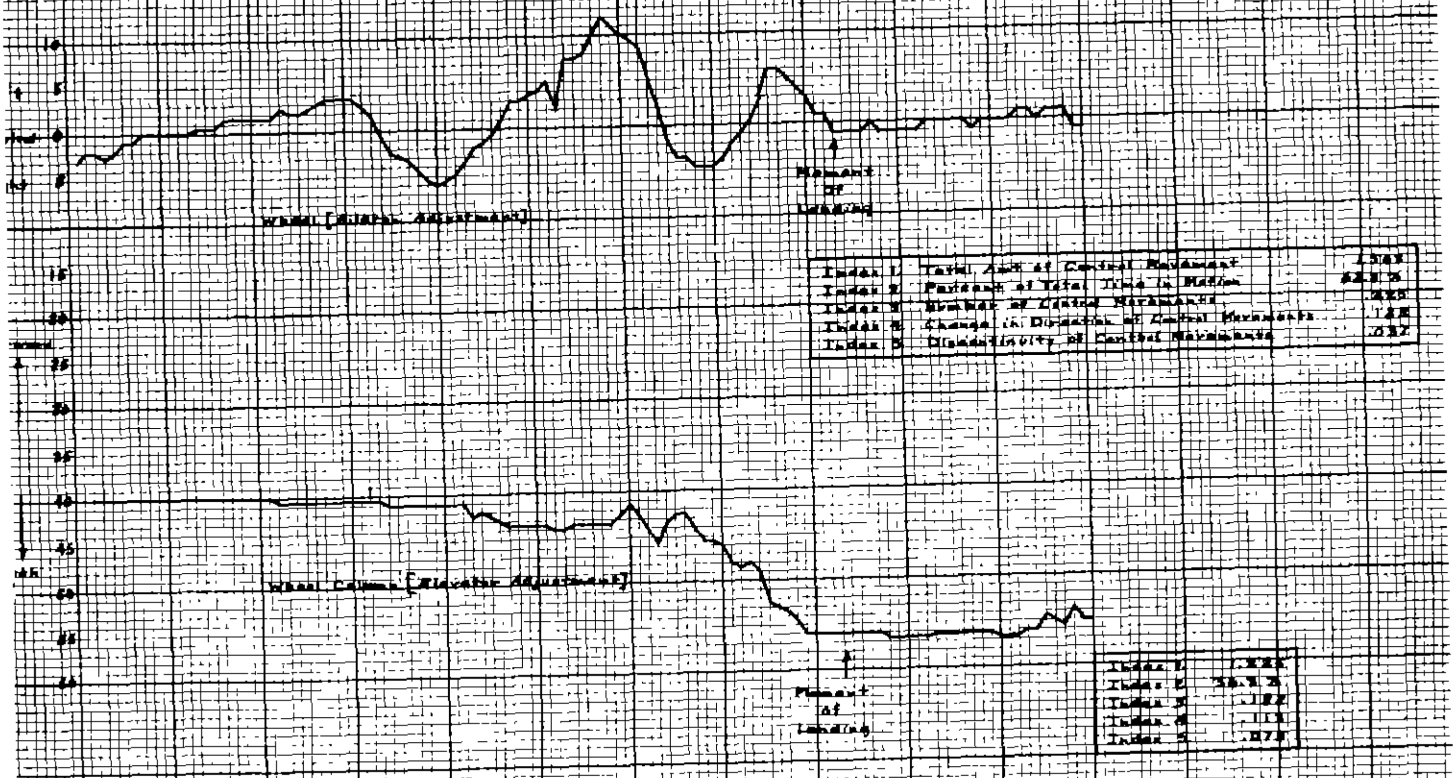
Index 1.	1.075
Index 2.	23.3 %
Index 3.	.125
Index 4.	.108
Index 5.	.075

Index 1.	1.002
Index 2.	2.5
Index 3.	.087
Index 4.	.067
Index 5.	.000


GRAPH Va
360° LEFT POWER TURN
"Superior" Pilot

GRAPH Vb
360° LEFT POWER TURN
"Inferior" Pilot

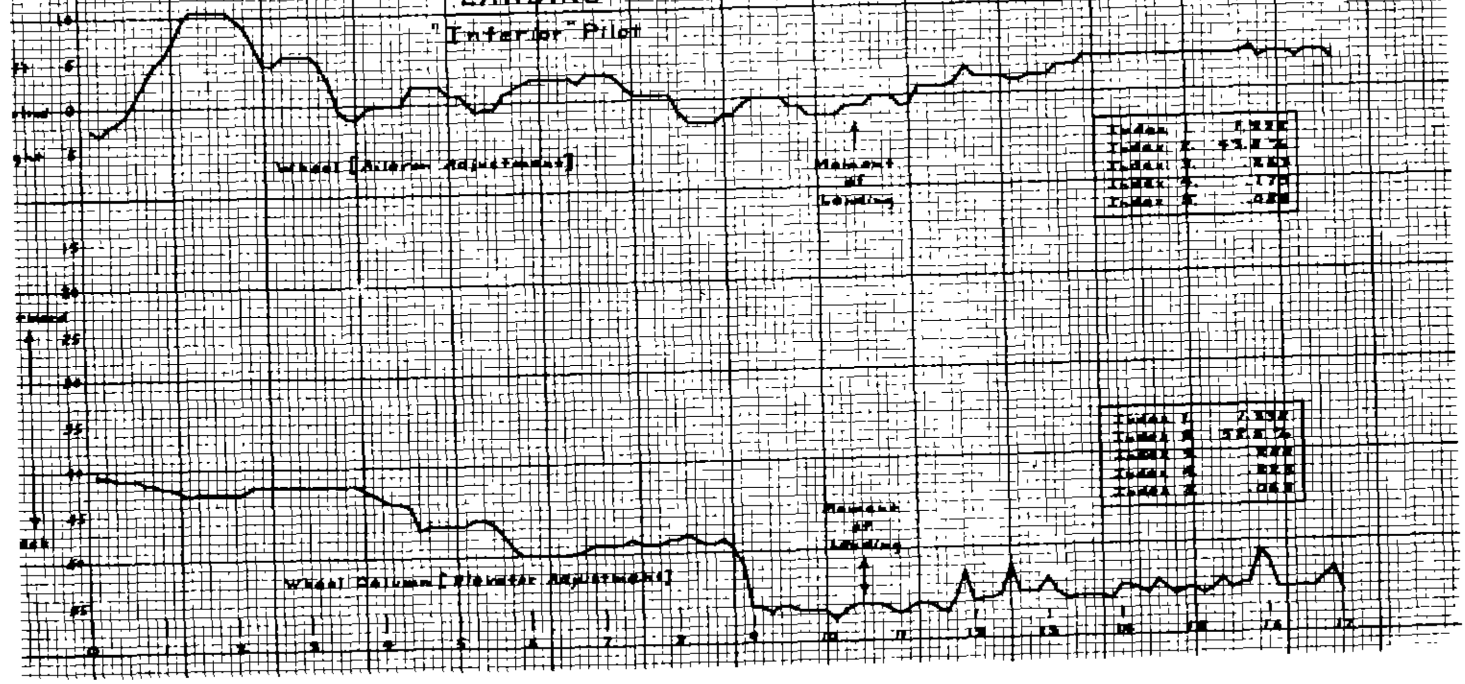
GRAPH VIA
LANDING
"Superior" Pilot



Index 1	Total Amt of Control Movement	[illegible]
Index 2	Percent of Total Time in Motion	62.3 %
Index 3	Number of Control Movements	.425
Index 4	Change in Direction of Control Movements	.148
Index 5	Discontinuity of Control Movements	.037

Index 1	1.223
Index 2	38.3 %
Index 3	.182
Index 4	.113
Index 5	.077

GRAPH VIB
LANDING
"Inferior" Pilot



Index	1.222
Index 2	43.2 %
Index 3	.263
Index 4	.170
Index 5	.038

Index 1	7.332
Index 2	57.2 %
Index 3	.222
Index 4	.222
Index 5	.062

THE USE OF STANDARD FLIGHTS AND MOTION PHOTOGRAPHY IN THE ANALYSIS OF AIRCRAFT PILOT PERFORMANCE

APPENDIX A

The Evaluation of Flying Habits and Flight Attitude by the Method of Direct Observation

Prepared by
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University of Pennsylvania

Philadelphia, Penna.

October, 1940

INTRODUCTION

1- Appendix A contains reports on three independent studies using the Procedure for Analysis of General Flying Habits of Pilots.

(a) The first study provided an analysis of the flying habits of 8 experienced pilots (flight instructors), piloting a wheel-type plane (Aeronca Chief). The report on this study, prepared on April 12, 1940, is given in section A of this Appendix.

(b) The second study, provided a similar analysis on a group of 7 experienced pilots (flight instructors), piloting a stick-type plane (Piper Cub). The report on this study, prepared on May 31, 1940, is given in section B of this Appendix.

(c) The third study provided information on the flying habits of 5 relatively inexperienced pilots (recently licensed students), piloting a wheel-type plane (Aeronca Chief). The report on this study, prepared on June 14, 1940, is given in section C of this Appendix.

2- (a) It should be noted that in the first study an attempt was made to analyze the cues used by the various subjects in judging plane attitude, response of plane to controls, need for control adjustment, etc. The information was obtained during a short conference with the subjects at the conclusion of the observation flights. Due to the difficulties experienced in obtaining valid introspections from naive subjects, and to the meagreness of the data, no conclusions concerning the use of cues on flying could be drawn and, in the two later studies, this part of the procedure was eliminated.

(b) The Procedure for Analysis of General Flying Habits, described briefly on page 3 of the main report, and in greater detail below, refers to the revised procedure used in the two later studies and in the co-ordinated projects at Rochester and Tulane.

PROCEDURE FOR ANALYSIS OF GENERAL FLYING HABITS OF PILOTS

1. Instructions to Subjects:

   "We are interested in observing how flyers pilot a plane through standard flights which have been developed. Study the diagrams carefully so that you are familiar with the flight. Fly naturally and easily and follow the course as closely as you can."

2. The diagrams of Standard Flights A and C1 were then shown to the subject and each maneuver was pointed out, stressing the character of the maneuver and the altitude at which it was to be performed. After the subject had become familiar with the diagrams, he was told that he would be kept posted during flight as to the next maneuver.

3. The subject then piloted the plane through Flight A with the observer calling out the maneuvers. During the flight the observer made notes on Methods of Handling Controls as outlined on Record Sheet 1, and on Evaluation of Flight as found on Record Sheet 2.

4. When Flight A was completed, Flight C1 was reviewed briefly with the subject before taking-off for Flight C1. During flight the observer checked and enlarged his observations on the Methods of Handling Controls and Evaluation of Flight.

5. At the conclusion of the flight the observer reviewed his notes on Evaluation and checked the Over-All Rating according to the five-point scale.

(Appendix - 3.)

Subject: Field:
Date: Wind:
Plane:

Record Sheet for Analysis of General Flying Habits

I. HANDLING OF CONTROLS:

A. Posture:

Position:

Changes of Position:

B. Throttle:

Grasping:

Moving:

Use of Lock:

Variations:

C. Rudder:

Position of Feet:

Changes of Position:

Extent of Leg Movements:

D. Wheel:

Grasping:

Variations in Grasping:

Moving Ailerons:

Moving Elevators:

(Appendix - 4.)

Subject:

Date:

Record Sheet for Analysis of General Flying Habits:

II. Evaluation of Flight:

Over-all Rating:
Excellent
Good
Average
Fair
Poor

A. Following Course:

1. Altitude:

2. Maneuvers:

3. Approaches:

4. Landings:

B. Turns:

1. Entry:

2. Bank:

3. Rate:

4. Recovery:

C. Angle of Climb and Glide:

D. Straight and Level Flight:

1. Constancy of Attitude:

2. Extent of Control Adjustment:

E. Throttle Control:

F. Traffic Check:

G. Comments:

(Appendix - 5.)

ANALYSIS OF GENERAL FLYING HABITS OF PILOTS

A. Instructors Piloting A Wheel-Type Plane

I. Purpose of Study:

The seeming contradiction between the common belief that expert pilots are able to maintain good plane attitude and carry out maneuvers equally well by the use of differing methods and the experience of industrial psychologists in the development of best methods of work in industry, suggested an investigation to determine the validity of the common belief. To this end an analysis of the flying habits of expert pilots was made to determine what, if any, flying habits were related to proficiency in piloting.

II. Method of Procedure: (see Procedure and Record Sheets for Analysis of General Flying Habits.)

The procedure involved the following steps:

1. Introductory remarks to the subject were made.
2. The subjects were familiarized with Standard Flights A and C1 through diagrams and the method of signalling during flight explained.
3. Subjects piloted the plane through Flight A; the observer made notes on posture and methods of manipulating throttle, rudder, and wheel.
4. Flight C1 was reviewed briefly and then flown; during the flight the observer checked and added to observations of Step 3.
5. Immediately after the flight, the observer had a short conference with the subject, obtaining information on cues used in flying.
6. After the conference, the observer made a subjective evaluation of the flight on the basis of observations made during the flight on: accuracy in following course, turns, angle of climb and glide, straight and level flight, throttle control, and traffic check.

The 8 members of the staff of flight instructors for the C.P.T. Program in the Philadelphia area were used as subjects. The observation flights lasted 30 minutes and the conference approximately 40 minutes. The planes used were Aeronca Chiefs.

III. Method of Treating Results:

On the basis of the flight evaluation the 8 instructors were ranked in order of proficiency. They were then divided into two groups -- the superior group composed of the four best pilots, and the inferior group composed of the four poorer pilots.

As a check on the validity of the ranking, the director of the local C.P.T. Program, who had selected and was in charge of the instructors, was asked to divide them into two groups according to his judgment of their flight proficiency. His grouping and the one obtained by us corresponded exactly.

All the items of observation were then tabulated and classified as to their being exhibited by the superior or inferior group. This classification made possible a comparison of the flying habits of the two groups and the segregation of the habits common to both groups and of those habits differentiating the groups.

IV. Results:

A. Posture:

Both groups sat erect and exhibited slight sway with turn.
One of each group cocked head to right during left 720°'s.
One of the inferior group moved body back and forth during landing.

B. Throttle:

Both groups used 1st finger as aid in fine adjustment of throttle.
All but one pilot held ball of throttle in palm.
One of the inferior group had 3 methods of grasping; two of the superior group had 2 methods; one for rapid changes and one for slight changes; the other 2 of the superior group had only one method.
Three of the superior group released throttle during 720°'s; two of the inferior group did likewise.
None of the superior group removed hand from throttle unless for use of right hand somewhere else; two of the inferior removed hand from throttle irregularly.

C. Rudder:

Both groups had same position of feet on rudder during taxi and flight.
Both groups used little leg movement. Note: Extent of leg movement may depend upon length of leg.

D. Wheel:

All but one held wheel with thumb toward body and fingers curled around wheel.
All used mostly arm movement for extensive movement of elevators (this must necessarily happen).
All of the superior group used finger and thumb for slight elevator pressures; two of the inferior group did likewise.
All of the superior group made most of the aileron adjustments with combination of wrist and slight arm movements; two of the inferior group used mostly arm movements for similar adjustments.
Only one of the superior group grasped wheel at left side during any maneuver; all four inferior pilots had hand at left side at some time during flight.
Three of the superior group used both hands on wheel in difficult maneuvers (720°'s, 8's and landings); one of the inferior group had both hands on wheel irregularly during flight and two not at all.
Only one of the superior group made more than slight shifts in location of hand on wheel; three of the inferior group made occasional or frequent shifts.
Three of the superior group used only one method of grasping wheel while in flight; two of the inferior group used three or four methods of grasping.

E. Cues Used in Flying:

All pilots placed primary dependence upon visual cues.
In determining wind direction, all of the superior group reported use of four or five cues; two of the inferior group only one of two cues.

In determining height of tail in take-off, all but one of the superior group reported cues besides visual; the inferior group reported only visual cues.

In determining attitude of plane in straight and level flight, the superior group reported only visual cues; the inferior group reported auditory and kinaesthetic cues as well as visual.

V. Summary of Common and Differentiating Flying Habits Exhibited by Superior and Inferior Groups:

A. Habits Common to Both Groups:

1. Posture:
   Both groups sat erect and exhibited slight sway with turns.
2. Throttle:
   a. Both groups used first finger along plunger as aid in fine adjustments.
   b. All but one pilot held ball of throttle in palm.
3. Rudder:
   a. Both groups had same position of feet on rudder during taxi and flight.
   b. Both groups exhibited little leg movement in moving rudder bar.
4. Wheel:
   a. All but one pilot held wheel with thumb toward body and fingers grasping wheel.
   b. All used mostly arm movements for extensive movements of elevators.
5. Cues:
   All pilots reported primary dependence upon visual cues.

B. Flying Habits Differentiating the Groups:

1. Posture:
   a. The only pilot exhibiting forward and back body movements was in the inferior group.
2. Throttle:
   Two of the inferior group exhibited irregularity in the method of grasping or in releasing of throttle during flight.
3. Rudder: None.
4. Wheel:
   a. Use of fingers and thumb for slight elevator pressure; exhibited by all of the superior group and by only two of the inferior group.
   b. Use of wrist and slight arm movement for aileron adjustments; exhibited by all of the superior group and by only one of the inferior group.
   c. Location of hand on wheel:
      Only one of the superior group grasped wheel at extreme left side during any maneuver; all of the inferior group grasped wheel at extreme left sometime during flight.
   d. Use of both hands on wheel:
      Three of the superior group used right hand to aid in difficult maneuvers (720°'s, 8's and landing); one of the inferior group had right hand on wheel irregularly and one not at all.

e. Frequency of shifting location of hand on wheel:
Only one of the superior group made more than slight, occasional shifts in location of hand on wheel; three of the inferior group made occasional or frequent shifts.

C. Cues in Flying Differentiating the Groups:

1. Wind Direction: all of the superior group reported use of four or five cues; two of the inferior group reported only one or two cues.
2. Height of Tail during Take-off Run: all but one of the superior group reported cues besides visual; the inferior group reported only visual cues.
3. Attitude of Plane: the superior group reported only visual cues; the inferior group reported auditory and kinaesthetic as well as visual cues.

VI. Conclusions:

A. Even pilots who can be classified as expert on the basis of their being selected as flight instructors for the C.P.T. Program, exhibit recognizable differences in proficiency and methods.

B. Expert pilots exhibit a common core of flying habits such as:
1. general body posture,
2. tendency of the body to sway slightly toward turns,
3. lack of leg movements in moving rudder,
4. position of feet on rudders during flight and taxi,
5. basic method of grasping throttle and wheel,
6. use of first finger to aid in fine throttle adjustment.

C. Flying habits differentiating superior from relatively inferior expert pilots occur. These habits may be of importance as discriminating items in the setting up of criteria and instruction programs. Differences characteristic of the superior group can be roughly classified as:

1. Less variability of methods employed as evidenced by:
    a. frequency of shifts of location of hand on wheel,
    b. variability of method of grasping or irregularity of release of throttle during flight,
    c. number of different methods of grasping wheel during flight.
2. Use of wrist and fingers rather than whole arm movements for manipulation of controls, especially for fine adjustments.
3. Transfer of throttle hand to wheel for assistance during difficult maneuvers.
4. Location of hand on or near top center of wheel.

D. No conclusions can safely be drawn concerning the use of cues in flying. The few differences which were reported may be due not to differences in the flying habits of the pilots but to differences in the completeness of their reporting of those habits. We are primarily interested in discovering what cues the expert pilot depends upon, rather than merely listing all the available cues: although the instructions to the subject emphasized the former, the reported cues may well be rendered unreliable due to the personal judgment involved.

These conclusions are preliminary, of course, since they are based on only eight subjects, all taken from the staff of one airport. They suggest, however, that there does exist a definite group of flying habits which result in optimum plane control and that extension of the investigation to include a similar analysis of other pilots and the use of more refined techniques, such as photographic and polygraphic recording, is justified.

VII. Classification of Flying Habits of Subjects:

(X indicates that the item of behavior was exhibited by the subject.

A. POSTURE:

	Erect	Sway with Turns	Cocked Head During Turns	Body Back & Forth During Landing
Superior Group:				
Subject 1	X	X	X (360°)	
Subject 2	X	X (very little)		
Subject 3	X	X (very little)		
Subject 4	X	X		
Inferior Group:				
Subject 1	X	X		X
Subject 2	X	X		
Subject 3	X	X	X	
Subject 4	X	X		

B. THROTTLE:

1. Method of Grasping:

	Ball in Palm	Between Fingers and Thumb	Used Finger for Slight Movements	Used More Than One Method of Grasping
Superior Group:				
Subject 1	X		X	
Subject 2	X		X	
Subject 3		X	X	X
Subject 4	X	X	X	X
Inferior Group:				
Subject 1	X	X	X(occasionally)	X(irregular change)
Subject 2	X		X	
Subject 3	X		X	
Subject 4	X	X	X	X(regular change)

2. Released Throttle During Flight:

	720° Turns	90° Turns	Figure 8's	Climb to 1500'	Landing	Irregularly
Superior Group:						
Subject 1	X		X		X	
Subject 2					X (few sec.)	
Subject 3	X					
Subject 4	X					
Inferior Group:						
Subject 1	X		X		X	X(no constant method)
Subject 2						
Subject 3						X(constant method but irregular release)
Subject 4	X	X	X	X	X	

C. RUDDER:

	Heels Off Floor During Taxi	Heels on Floor During Taxi	No Leg Movements Except in Taxi
Superior Group:			
Subject 1	X	X	X
Subject 2	X	X	X
Subject 3	X	X	X
Subject 4	X	X	X (slight)
Inferior Group:			
Subject 1	X	X	X (slight)
Subject 2	X	X	X
Subject 3	X	X	X (slight)
Subject 4	X	X	X

D. WHEEL:

1. Location of Hand on Wheel:

	Grasped Wheel at Center	Grasped Wheel toward Left Side	Grasped Wheel At Left Side
Superior Group:			
Subject 1	X		
Subject 2		X	
Subject 3	X	X	X (taxi)
Subject 4	X	X	
Inferior Group:			
Subject 1			X
Subject 2	X	X	X
Subject 3	X	X	X
Subject 4	X		X (few sec.)

2. Use of Both Hands on Wheel:

	720°'s	Fig. 8's	Landing	Irregularly	Not at All
Superior Group:					
Subject 1	X	X	X		
Subject 2			X (few sec.)		
Subject 3	X				
Subject 4	X				
Inferior Group:					
Subject 1	X	X	X		
Subject 2					X
Subject 3				X	
Subject 4					X

3. Frequency of Shifting Position:

Superior Group:

Subject 1 - least
Subject 2 - only in 720°'s
Subject 3 - regular shifts from side to center
Subject 4 - occasional (slight)

Inferior Group:

Subject 1 - occasional
Subject 2 - occasional
Subject 3 - frequent
Subject 4 - occasional

D. WHEEL: (Continued)

4. Movement of Ailerons:

	Mostly Wrist & Fingers	Slight Arm	Mostly Arm
Superior Group:			
Subject 1	X		
Subject 2		X	
Subject 3		X	
Subject 4		X	
Inferior Group:			
Subject 1			X
Subject 2			X
Subject 3	X	X	
Subject 4		X	

5. Movement of Elevators:

	Fingers & Thumb for Slight Pressure	Arm Movement for Greater Pressure
Superior Group:		
Subject 1	X	X
Subject 2	X	X
Subject 3	X	X
Subject 4	X	X
Inferior Group:		
Subject 1		X
Subject 2	X	X
Subject 3		X
Subject 4	X	

6. Methods of Grasping During Flight:

	Fingers Around Wheel - Thumb Toward Body	Palm Down with Center Bar Between Fingers	Between Thumb and Finger Only	Grasped Around Center Bar	Finger Tips Resting on Wheel
Superior Group:					
Subject 1	X				
Subject 2	X				
Subject 3		X (flight)			
Subject 4	X	X			X(during long run)
Inferior Group:					
Subject 1	X				
Subject 2	X				
Subject 3		X	X	X	
Subject 4	X	X	X(few sec)		

ANALYSIS OF GENERAL FLYING HABITS OF PILOTS

B. Instructors Piloting a Stick-Type Plane

I. Procedure:

Seven flight instructors were observed according to the "Method of Analysis of General Flying Habits" described in the April 12th report. The subjects include the five instructors at the College Park, Maryland, Airport and two of the three instructors at the Bloomington, Indiana, airport. All piloted a Piper Cub plane which uses a stick for aileron and elevator control.

On the basis of the flight evaluation, the subjects were ranked in order of proficiency and then divided into two groups - the "superior" group composed of the four better pilots, and the "inferior" group composed of the three poorer pilots.

The observed methods of handling controls were then tabulated and classified as to their being exhibited by the two groups.

II. Classification of Flying Habits of Subjects:

A. POSTURE:

Superior Group	Erect	Body Turned Sidewise	Swayed During Turns
Subject 1	X		X (toward)
Subject 2	X		X (toward)
Subject 3	X	X	X (away)
Subject 4	X	X (during 8's)	X (toward)
Inferior Group			
Subject 1	X	X	X (forward in take-off)
Subject 2	X		X (toward)
Subject 3	X		

B. THROTTLE:

1. Method of Grasping:

Superior Group	Hand Resting on Side of Plane; Throttle between Thumb & 1st Fingers	Variations During Maneuvers
Subject 1	X	
Subject 2	X	
Subject 3	X	X (released occasionally)
Subject 4	X	X (throttle in palm)
Inferior Group		
Subject 1	X	X
Subject 2	X	
Subject 3	X	

B. THROTTLE: (Continued)

2. Moving of Throttle:

	Mostly Fingers	Mostly Wrist	Mostly Arm
Superior Group:			
Subject 1		X	
Subject 2		X	
Subject 3	X		
Subject 4		X	X (occasionally)
Inferior Group:			
Subject 1		X	
Subject 2		X	
Subject 3		X	

C. RUDDER

Note: It was impossible to observe position and use of feet in rudder controls.

D. STICK:

1. Method of Grasping:

	Location of Thumb		Fingers Encircled Stick
Superior Group:	On Top	On Side	
Subject 1		X	X
Subject 2		X	X
Subject 3	X		X
Subject 4	X		X
Inferior Group:			
Subject 1	X		X
Subject 2		X	X
Subject 3		X	

2. Variations in Grasping:

Superior Group:	Released or Shifted Thumb	Released Stick Entirely During Flight
Subject 1	X	
Subject 2	X	X (during 1500' climb merely rested hand on top of stick)
Subject 3	X	
Subject 4	X	
Inferior Group:		
Subject 1	X	
Subject 2		X (during 1500' climb & return to field)
Subject 3		X (occasionally)

D. STICK: (Continued)

3. Moving Stick for Aileron Adjustment:

	Mostly Finger Movement	Mostly Wrist Movement	Mostly Whole Arm Movement	Rested Arm on Leg For Steady Control
Superior Group:				
Subject 1		X		X
Subject 2			X	
Subject 3		X		X
Subject 4			X	X
Inferior Group				
Subject 1			X	
Subject 2			X	
Subject 3	X			X

4. Moving Stick for Elevator Adjustment:

	Used Mere Tightening of Grasp for Slight Adjustments	Mostly Wrist Movement	Mostly Arm Movement	In Glide, Let Stick Rest Against Finger
Superior Group:				
Subject 1		X		X
Subject 2		X		X
Subject 3	X	X		
Subject 4		X		
Inferior Group:				
Subject 1			X	
Subject 2			X	
Subject 3	X			

III. Summary of Common and Differentiating Flying Habits Exhibited by Superior and Inferior Groups:

A. Habits Common to Both Groups:

1. Posture:

Both groups sat erect and relaxed.
Five of the seven pilots swayed with the turns.

2. Throttle:

Both groups held the throttle between thumb and fingers, while resting hand on side of plane.
Six of the seven pilots made throttle adjustments largely by a forward and backward wrist movement.

3. Stick:

Six of the seven pilots grasped the stick with thumb on top or on side with fingers encircling the stick in rather loose grasp.

B. Habits Differentiating the Two Groups:

1. All of the "superior" group and only one of the "inferior" group released or shifted position of the thumb during the flight.

2. Two of the "inferior" group released the stick entirely for a certain period during flight.

3. Aileron adjustments by the "superior" group were characterized by a combination of wrist and arm movements steadied by resting the arm on the right leg. Two of the three "inferior" pilots used mostly free arm movements while the third used finger movements almost entirely, except for the extensive adjustments.

4. Elevators adjustments by the "superior" group were characterized by a combination of wrist movement and tightening of the fingers for the less extensive adjustments. Two of the three "inferior" pilots used mostly free arm movements.

5. The two best pilots let the weight of the stick rest loosely against the hand during glides.

IV. Conclusions:

A. The conclusion (previously made on the basis of observation of eight pilots on the Aeronca Chief) that even experienced pilots exhibit recognizable differences in proficiency and methods is confirmed.

B. A common core of flying habits in the entire group was observed, including:

1. Erect and relaxed posture with tendency to sway with the turns.

2. A tendency to grasp the throttle between the thumb and fingers with the hand resting on the side of the plane, and to move the throttle with a forward and backward wrist movement.

3. A tendency to grasp the stick between the thumb and encircled fingers in a rather loose grasp.

C. Habits differentiating the "superior" from the "inferior" pilots included:

1. Shifting or releasing the thumb on the stick.

2. Resting the arm on the right leg and using the latter to steady the control of the stick for aileron adjustments rather than letting the arm hang free.

3. Making the less extensive elevator adjustments by a combination of wrist movements and tightening of the finger grasp.

(Appendix - 17.)

ANALYSIS OF GENERAL FLYING HABITS OF PILOTS

C. Recently Licensed Students Piloting A Wheel-Type Plane

I. Procedure:

Five students who had just previously obtained their private flying licenses in the local C.P.T. Program, were observed according to the "Procedure for Analysis of General Flying Habits", as described above. The plane used was an Aeronca Chief.

On the basis of the flight evaluations, the subjects were ranked in order of proficiency and then divided into two groups: the "superior" group, composed of the two better pilots; and the "inferior" group, composed of the three poorer pilots. The observed methods of handling the controls were then tabulated and classified as to their being exhibited by the two groups.

II. Classification of Flying Habits of the Student Group:

A. POSTURE:

	Erect	Sway in Turns	Considerable Body Movement
Superior Group:			
Subject 1	X		
Sunject 2	X	X (toward)	
Inferior Group:			
Subject 1	X	X	
Subject 2	X	X (toward)	
Subject 3	X	X (away)	X

B. THROTTLE:

	Ball in Palm	Mostly Full-Arm Movements	Finger Along Plunger For Slight Movements	Used Look
Superior Group:				
Subject 1	X		X	in 8's
Subject 2	X	X	(occasionally)	8's & levelling off
Inferior Group:				
Subject 1	X	X	X	
Subject 2	X		X	
Subject 3	X	X	X	

C. RUDDER:

	Basic Position of Heels on Floor & Ball of Feet on Bar	Heels Off Floor During Taxi	Extent of Leg Movements During Flight
Superior Group:			
Subject 1	X		Slight
Subject 2	X	X	Slight
Inferior Group:			
Subject 1	X		Slight
Subject 2	X	X	Slight
Subject 3	X		Occasional side to side move-

D. WHEEL:

1. Location of Hand on Wheel:

	At Center	Toward Left Side	At Left Side	Shifts in Location
Superior Group:				
Subject 1	X			
Subject 2	X			
Inferior Group:				
Subject 1	X			
Subject 2	X			During 8's
Subject 3	X			

2. Use of Both Hands on Wheel:

	720's	Figure 8's	Take-Off	Landing	Irregularly	Not At All
Superior Group:						
Subject 1						X
Subject 2			X			
Inferior Group:						
Subject 1						X
Subject 2	X		X			
Subject 3		X				

3. Method of Grasping:

	Palm on Top Center Bar Between Fingers	Palm on Top - slightly to Left of Center Bar Thumb Along Wheel Rim	Fingers on Top-Palm Toward Wheel Thumb Along Rim
Superior Group:			
Subject 1	X		
Subject 2		X	
Inferior Group:			
Subject 1		X	
Subject 2			X
Subject 3		X	

4. Method of Moving Wheel:

	Mostly Arm Movements	Wrist and Slight Arm Movements	Fingers For Slight Pressure
Superior Group:			
Subject 1		X	X
Subject 2		X	
Inferior Group:			
Subject 1	X	X	
Subject 2		X	X
Subject 3	X		

III. Summary of Results:

A. Posture:

Both groups sat erect and exhibited slight sway in turns.
Only one subject (the poorest) leaned away from the turns.
Only one subject (the poorest) exhibited irregular and considerable body movement during flight.

B. Throttle:

Both groups held throttle ball in palm of hand and finger along plunger.
Both subjects of the "superior" group and none of the "inferior" group used the throttle lock for certain maneuvers.

C. Rudder:

Both groups exhibited the same basic foot position on the rudder bar.
Only one subject (the poorest) made other than slight leg movements during flight.

D. Wheel:

1. Location of Hand on Wheel:

   Both groups held the wheel at the center.
   Only one subject (in the "inferior" group) shifted location of hand on wheel during flight.

2. Use of Both Hands on Wheel:

   One of the "superior" and one of the "inferior" groups used only one hand throughout.
   The other subjects used right hand to assist in certain maneuvers.

3. Method of Grasping:

   All but one of the subjects (in the "inferior" group) grasped the wheel by placing the palm on top and encircling the fingers about the rim with thumb extended along rim.
   The best subject held the center bar between the second and third fingers.
   One of the "inferior" group grasped the wheel by placing the palm toward the wheel with the fingers on top, the thumb extending along the rim.

4. Method of Moving Wheel:

   Two of the three subjects in the "inferior" group and none in the "superior" group used mostly arm movements for moving wheel. The others used mostly wrist and slight arm movements.
   One of each group used fingers for slight pressures on wheel.

IV. Summary of Common and Differentiating Flying Habits Exhibited by Superior and Inferior Groups:

A. Habits Common to Both Groups:

1. Posture:

Both groups sat erect and exhibited slight sway in turns.

2. Throttle:

Both groups used a similar method for grasping the throttle.

3. Rudder:

Both groups exhibited same basic foot position on the rudder bar.
Both groups made only slight leg movements during flight.

4. Wheel:

Both groups held the wheel at the center.
Neither group exhibited a tendency to make frequent shifts of location of hand on wheel.
Both groups used a similar method of grasping the wheel.

B. Flying Habits Differentiating the Groups:

1. Posture:

The poorest subject leaned away from rather than toward the turns and exhibited irregular and considerable body movement during flight.

2. Throttle:

Those in the "superior" group tended to use the throttle lock occasionally.

3. Rudder:

The poorest subject was the only one making other than slight leg movements during flight.

4. Wheel:

The only subject shifting location of hand on wheel was in the "inferior" group.
The best and the poorest subject used a method of grasping wheel slightly different from that of the other subjects.
The "superior" group tended to use mostly wrist and slight arm movements rather than whole arm movements for changing the wheel position during flight.

V. Discussion and Conclusions:

This investigation, like those made on the other groups of subjects, indicates that there are habits common to superior and inferior pilots and that there are habits differentiating the two groups.

Comparison of the results of this investigation with those of the study using the flight instructors as subjects reveals the following:

A. Habits Common to Both Inferior and Superior Subjects in Both Investigations are:

1. Erect posture and sway with turns.
2. Basic method of grasping throttle and wheel.
3. Position of feet on rudder bar.
4. Lack of extensive leg movements in moving rudder bar.
5. Use of finger to aid in fine throttle adjustments.

B. Habits Common to the Students but Differentiating the Superior and Inferior Instructors are:

1. Location of hand at or near top center of wheel.
2. Lack of shifts of location of hand on wheel.

C. Habits Exhibited by Inferior Subjects in Both Studies are:

1. Irregular and considerable body movements during flight.
2. Use of wrist and slight arm movement for slight aileron and elevator adjustments.

D. Other Findings are:

1. The use of both hands on the wheel during certain maneuvers was characteristic of the "superior" subjects in the Instructor Group but not in the Student Group.

2. None of the students exhibited the variability of method of grasping and moving controls characteristic of the "inferior" Instructor Group.

3. The "superior" Instructor Group exhibited a greater use of fingers and thumb for slight elevator pressures than did the students as a whole.

THE USE OF STANDARD FLIGHTS AND MOTION PHOTOGRAPHY IN THE ANALYSIS OF AIRCRAFT PILOT PERFORMANCE

SUPPLEMENTAL REPORT

Manual of Standard Check Flight Procedures for Civilian Pilot Training*

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May, 1943

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* Also issued as Standard Check Flight Procedures, Bulletin No. 1, Division of Research, Civil Aeronautics Administration, Washington, D. C.

INTRODUCTION

One major responsibility of C.P.T. instructors in giving flight training is to determine the progress which is being made by the student. At every stage of the instruction program the instructor must "size-up" the student in terms of the skill which he is developing in handling the plane.

This rating on skill is perhaps particularly important at the end of Stage A, when the instructor assumes considerable responsibility for the safety of the student in deciding whether he has acquired sufficient skill to be sent up on a solo flight. At the end of Stage D, the instructor must make another crucial decision in passing judgment on whether the student is ready for the final flight test.

The fact that the C.P.T. program gives the instructor the authority to hold the student in each stage until the desired level of skill is exhibited is evidence of the instructor's responsibility in making estimates of the student's proficiency in piloting a plane.

Experience in industry has demonstrated that ratings on skill can be made most easily and most accurately when apprentices or workers who are being rated by foremen or supervisors are all given the same thing to do, i.e. when the task, the conditions, the tools, etc. are the same for each individual. Only under such conditions can observed differences in performance be attributed primarily to differences in skill or proficiency.

THE STANDARD FLIGHT IN PILOT TRAINING

It is believed that this principle of the standard task can be profitably applied by C.P.T.P. instructors as an aid in facilitating and improving judgments on the skill of student pilots. This involves the use of standard flights, given under essentially uniform conditions, as a substitute for the somewhat informal check flights which are at present used at stated intervals in the instruction program.

The basic characteristic of the standard flight is that it requires each student at the same level of training to perform the same maneuvers, in the same order, under essentially the same conditions. The nature of such a standard flight is apparent in Exhibit 1, which shows a standard flight developed for use with students completing Stage A of training at the Boston Metropolitan Airport, Norwood, Mass.

Before discussing the details of this and similar flights, it is important to note that the use of standard flighte does not impose any extra burden upon the instructor. The present C.P.T. program actually calls for check flights to be given by the instructor during Lesson 16 in Stage A, Lesson 11 in Stage B, Lesson 15 in Stage C and Lesson 8 in Stage D. The necessity for uniformity in check flights is also recognized. So, for example, in connection with Lesson 16, Stage A, it is suggested that "the instructor should definitely have in mind which maneuvers are to be practiced and give them to the student in the logical sequence to conserve time, and altitude in the air." Likewise, the Suggested Flight Plan for Lesson 8, Stage D, states that "the student should be given a complete flight test by the instructor, who will ride as a check pilot and grade him as though it were an actual examination . . . The same sequence of maneuvers and manner of giving the test should be followed as in an actual test for certification."

The fundamental purpose of the standard flight is to ensure the uniformity of check flights by setting down the sequence of maneuvers to be used during check flights in each stage of instruction. As indicated above, Exhibit 1 describes a standard flight suitable for students completing Stage A of the C.P.T. program. It can be seen, from both the diagram and accompanying description, that it includes the basic maneuvers of Stage A instruction, namely- Taxi, Take-Off, 90° Climbing Turn, Straight Glide, 90° Medium Turn, Straight Climb, Straight and Level Flight, Rectangular Course, S-Turns Across a Road, and 90° Approach and Landing. However, the maneuvers are combined into a definite flight pattern with specifications for wind direction, altitude, and local traffic rules.

An examination of Exhibit 1 also shows that maneuvers included in the flight are of two types - critical maneuvers (in solid lines), and transition maneuvers (in dotted lines). The purpose of the flight is to give the instructor an opportunity to observe student performance during the critical maneuvers. The transition maneuvers are simply included where necessary and as necessary to place the plane into a position for the succeeding critical maneuver.

Transition maneuvers will naturally vary from field to field depending upon the layout of the field and local conditions and requirements. The nature of such variations in transition maneuvers can be seen from a comparison of Exhibit 1 with Exhibit 2 which includes a diagram and description of Standard Flight A as designed for Municipal Airport, Philadelphia.

Transition maneuvers will vary not only from airport to airport, but will also vary at the same airport with wind direction. For this reason, in using standard flights, it is necessary to provide diagrams showing the actual flight paths under varying wind conditions, involving the use of different runways for take-off and landing. In Exhibits A to G, of Appendix I, are shown changes necessary in a standard flight diagram to show variations in transition manouvers related to the wind conditions and the runway used.

Standard flights suitable for later phases in the training program are illustrated in Exhibit 3, Exhibit 4, and Exhibit 5 respectively. It should be noted that each of the advanced flights is composed essentially of manouvers added on to the preceding standard flight. Repetition of maneuvers characteristic of instruction of stages preceding the one covered by advanced standard flights is especially important because it provides for a review of the basic skills necessary for satisfactory performance of the more advanced manouvers.

PREPARATION OF STANDARD FLIGHTS FOR LOCAL AIRPORT

Instructors who are interested in using standard flights of the type described above will find it a relatively simple matter to prepare a similar series of standard check flights for their local airport. Steps to be taken in duplicating such standard flights to be used under local conditions are somewhat as follows:

1 - Examine the sample flight descriptions and diagrams for instances in which the local traffic and terrain conditions require changes as to flight path, altitude specifications, etc.

2 - Prepare flight descriptions and diagrams incorporating the changes made necessary by the local airport.

INSTRUCTIONS FOR USE OF STANDARD FLIGHTS

Instructors will, of course, have their own ideas with respect to how standard flights may best be employed. However, experience with such standard flights on an experimental basis in various parts of the country has suggested the following steps as being of particular importance.

1 - Standard check flights should be made under essentially similar weather conditions.*

2 - Each flight must be given to each student at approximately the same learning stage, that is within a narrow range of hours of instruction.**

3 - Copies of the standard flight diagrams and flight descriptions should be made available for examination by the student at all times. This can most conveniently be done by posting a flight diagram and flight description in the hangar or "ready room." The significance of check flights is increased when students are made familiar with the details of the flight to be made.

4 - Instructions used in giving standard flights must be standard for all students and adequate time and favorable conditions should be provided for going over the instructions with the students immediately prior to the check flight. Following

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(*) In one experimental center it was agreed that the following conditions should apply in giving Standard Check Flights:

- (a) Wind velocity: from 3 to 8 miles per hour. Local research groups should provide a velocity recorder if the airport does not have one.
- (b) Wind turbulence: not excessive.
- (c) Visibility: minimum of 5 miles.

However, it must be recognized that these conditions must be set up in relation to weather conditions applying to the local airport.

(**) The following time distributions have been used in one experimental center:

	Hours of Instruction Completed by Student			
	Min.	Max.	Mid-point	Within
Flight A	4	6	5	Stage A
Flight B	10	13	11.5	Stage B
Flight C	21	24	22.5	Stage C
Flight D	32	36	34.0	Stage D

Here again instructors will use their best judgment in setting up the range of hours applying to each check flight at each stage of instruction.

is a sample of instructions which have been employed for this purpose.

"We are going to make a check flight to see how you have developed up to the present stage of your instruction. This flight requires you to fly a given set of maneuvers in a particular order and at designated altitudes. Here are a description and diagram of the flight." (The instructor will then go over with the student the description and diagram of the flight, pointing out the order of the maneuvers and the specifications as to wind direction, altitude, etc.) "You are not expected to make this flight from memory. During the flight each maneuver will be announced in its proper order and you will be told the appropriate altitude for each maneuver and be given a signal at the start of each maneuver."

"Are there any questions as to the flight? Remember, all I'm asking is that you do as well as you can, performing the maneuvers of the flight as carefully as possible. During the flight make certain that you understand exactly what is to be done before starting each maneuver."

5 - In general the following procedures should be employed during the standard check flight.

A. Immediately before each critical maneuver, give clear concise instructions, as to altitude requirements, ground reference points when necessary, specifications as to bank and degree of turn, wind direction, etc. Use the specifications as given in the standard flight descriptions prepared for the local airport.

B. Make certain that the plane is in correct position before giving the signal for each successive maneuver. If the correct flight path is interrupted by a student error or by traffic conditions, regain correct position during the succeeding transition maneuver.

C. During transition maneuver A, if the student is unable to trim the ship properly, do it for him after giving him ample opportunity to do so himself.

D. Remember that these flights are check flights, not instruction flights: make no comments to the student as to the quality of the latter's performance and do not take over the controls for corrective purposes, except in the case of emergencies, or, except in transition maneuvers in order to regain the correct flight path.

GENERAL

A fair trial of the above program should result in more reliable judgments on student skill in piloting. Success in the use of the flights depends essentially upon the care with which instructors adapt the standard flights to the flight locality and upon their adherence to standard conditions in administering so as to provide comparable flight situations for all students.

Exhibits 1 to 5

Exhibit 1.

STANDARD FLIGHT A

This flight includes the basic maneuvers taught in Stage A of the C.P.T program and describes the flight to be made by the student pilots while being observed and photographed.

The "critical maneuver", representing those maneuvers which are being studied, are designated by numbers and are capitalized. The intervening maneuvers are "transition maneuvers", representing those maneuvers whose purpose is to get the plane into position for the next critical maneuver.

Order and Description of Maneuvers

1. TAXI: to take-off line plus right pivot for observation of approaching aircraft and turn back into wind.

2. TAKE-OFF: into wind or as near as appropriate runway allows.

3. STRAIGHT CLIMB: to altitude of 600', attaining optimum climbing speed.

4. 90° LEFT CLIMBING TURN: to 90° angle from take-off direction. This turn should be long, shallow turn, gradual enough to permit turn into wind in case of engine failure.

   Transition Maneuver A: Proceed (around airport, if necessary) to practice area appropriate for the wind direction, attaining altitude of 1000' on route. While flying to practice area make certain that the plane is properly trimmed for straight & level flight. After reaching practice area head into wind in correct position for succeeding maneuver.

5. STRAIGHT GLIDE: into wind with optimum gliding angle, beginning at 1000' and recovering at 700'.

   Transition Maneuver B: short straight and level flight, at 700', heading into wind.

6. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting into wind and ending in cross-wind direction.

   Transition Maneuver C: short straight and level flight at 700', heading in cross-wind direction.

7. 90° MEDIUM LEFT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

   Transition Maneuver D: short straight and level flight, at 700' altitude, heading into wind.

8. 90° MEDIUM LEFT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting into wind and ending in cross-wind direction.

   Transition Maneuver E: short straight and level flight at 700', heading cross-wind.

9. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

   Transition Maneuver F: short straight and level flight at 700', heading into wind.

10. STRAIGHT CLIMB: into wind with optimum climbing angle, starting at 700' altitude and levelling off at 1000'.

Transition Maneuver G: maintaining altitude of 1000', turn down wind.

11. STRAIGHT AND LEVEL FLIGHT: down wind at cruising speed at altitude of 1000', obtaining straight and level flight as soon as possible and maintaining straight and level flight until observer gives signal for next Maneuver.

Transition Maneuver H: upon instruction from observer, proceed to correct location for succeeding maneuver, maintaining altitude of 1000'. Ground reference points for rectangular course will be pointed out by the observer.

12. RECTANGULAR COURSE: begin into wind, parallel to one side of the rectangular course, and make four turns to left, ending maneuver immediately after fourth turn and when heading straight into wind.

Transition Maneuver I: upon instruction from observer, proceed to correct location for succeeding maneuver, maintaining altitude of 1000'.

13. S-TURNS ACROSS ROAD: begin into wind and make first turn to left. Continue maneuver until two left and two right 180° turns are made, ending maneuver heading into wind.

Transition Maneuver J: upon instruction from observer, return to airport, maintaining altitude of 1000'. Proceed to key position for 90° approach to landing.

14. 90° APPROACH TO LANDING: from altitude of 1000'
   (a) Straight Glide: after closing throttle at key position
   (b) 90° Left Gliding Turn: until heading into wind

15. FINAL APPROACH AND LANDING: into wind, beginning final approach at least 1000' from airport boundary.

16. LANDING RUN: at least 100' without use of brakes.

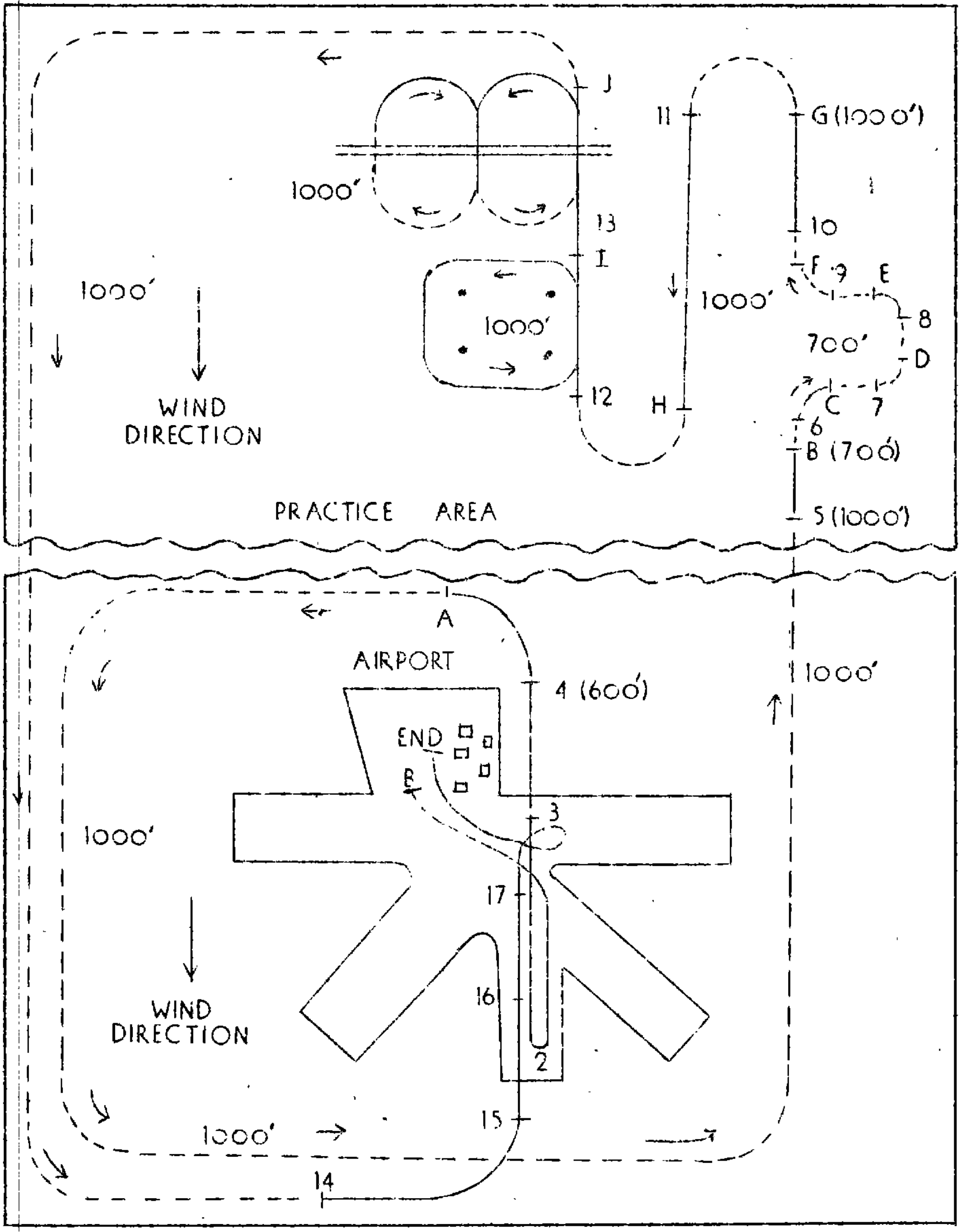
17. PIVOT TURN AND TAXI: to desired position.

Prepared by: Morris S. Viteles & Albert S. Thompson

For use at: Boston Metropolitan Airport, Norwood, Mass.
Muller Field, Revere, Mass.

Exhibit 1

STANDARD FLIGHT A
(for use at Boston Metropolitan Airport, Norwood, Mass.)
Wind Direction: Southwest



Prepared by: Morris S. Viteles
Albert S. Thompson
Univ. of Penna.

Exhibit 2

STANDARD FLIGHT A

This flight includes the basic maneuvers taught in Stage A of the C.P.T. program and describes the flight to be made by the student pilots while being observed.

The "critical maneuvers", representing those maneuvers which are being studied, are designated by numbers and are capitalized. The intervening maneuvers are "transition maneuvers", representing those maneuvers whose purpose is to get the plane into position for the next critical maneuver.

<u>Order and description of Maneuvers</u>

1. TAXI: to take-off line plus right pivot turn for observation of approaching aircraft and turn back into wind.

2. TAKE-OFF: into wind or as near as appropriate runway allows.

3. STRAIGHT CLIMB: to altitude of 600', attaining optimum climbing speed.

4. 90° LEFT CLIMBING TURN: to 90° angle from take-off direction. This turn should be long, shallow turn, gradual enough to permit turn into wind in case of engine failure.

   Transition Maneuver A: Proceed (around airport, if necessary) to correct location for crossing river, attaining altitude of 1000' enroute. Cross river at altitude of 1000' and proceed to practice area. While flying to practice area make certain that the plane is properly trimmed for straight and level flight. After reaching practice area head into wind in correct position for succeeding maneuver.

5. STRAIGHT GLIDE: into wind with optimum gliding angle, beginning at 1000' and recovering at 700'.

   Transition Maneuver B: short straight and level flight, at 700', heading into wind.

6. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

   Transition Maneuver C: short straight and level flight at 700' heading in cross-wind direction.

7. 90° MEDIUM LEFT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

   Transition Maneuver D: short straight and level flight, at 700' altitude, heading into wind.

8. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting

into wind and ending in cross-wind direction.

Transition Maneuver E: short straight and level flight at 700', heading cross-wind.

9. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

Transition Maneuver F: short straight and level flight at 700', heading into wind.

10. STRAIGHT CLIMB: into wind with optimum climbing angle, starting at 700' altitude and levelling off at 1000'.

Transition Maneuver G: maintaining altitude of 1000', turn down wind.

11. STRAIGHT AND LEVEL FLIGHT: down wind at cruising speed at altitude of 1000', obtaining straight and level flight as soon as possible and maintaining straight and level flight until observer gives signal for next Maneuver.

Transition Maneuver H: upon instruction from observer, proceed to correct location for succeeding maneuver, maintaining altitude of 1000'. Ground reference points for rectangular course will be pointed out by the observer.

12. RECTANGULAR COURSE: begin into wind, parallel to one side of the rectangular course, and make four turns to left, ending maneuver immediately after fourth turn and when heading straight into wind.

Transition Maneuver I: upon instruction from observer, proceed to correct location for succeeding maneuver, maintaining altitude of 1000'.

13. S-TURNS ACROSS ROAD: begin into wind and make first turn to left. Continue maneuver until two left and two right 180° turns are made, ending maneuver heading into wind.

Transition Maneuver J: upon instruction from observer, return to airport, maintaining altitude of 1000'. After crossing river reduce altitude to 600' and proceed to key position for 90° approach.

14. 90° APPROACH TO LANDING: from altitude of 600'.
    (a) Straight Glide: after closing throttle at key position.
    (b) 90° Left Gliding Turn: until heading into wind.

15. FINAL APPROACH AND LANDING: into wind, beginning final approach at least 1000' from airport boundary.

16. LANDING RUN: at least 100' without use of brakes.

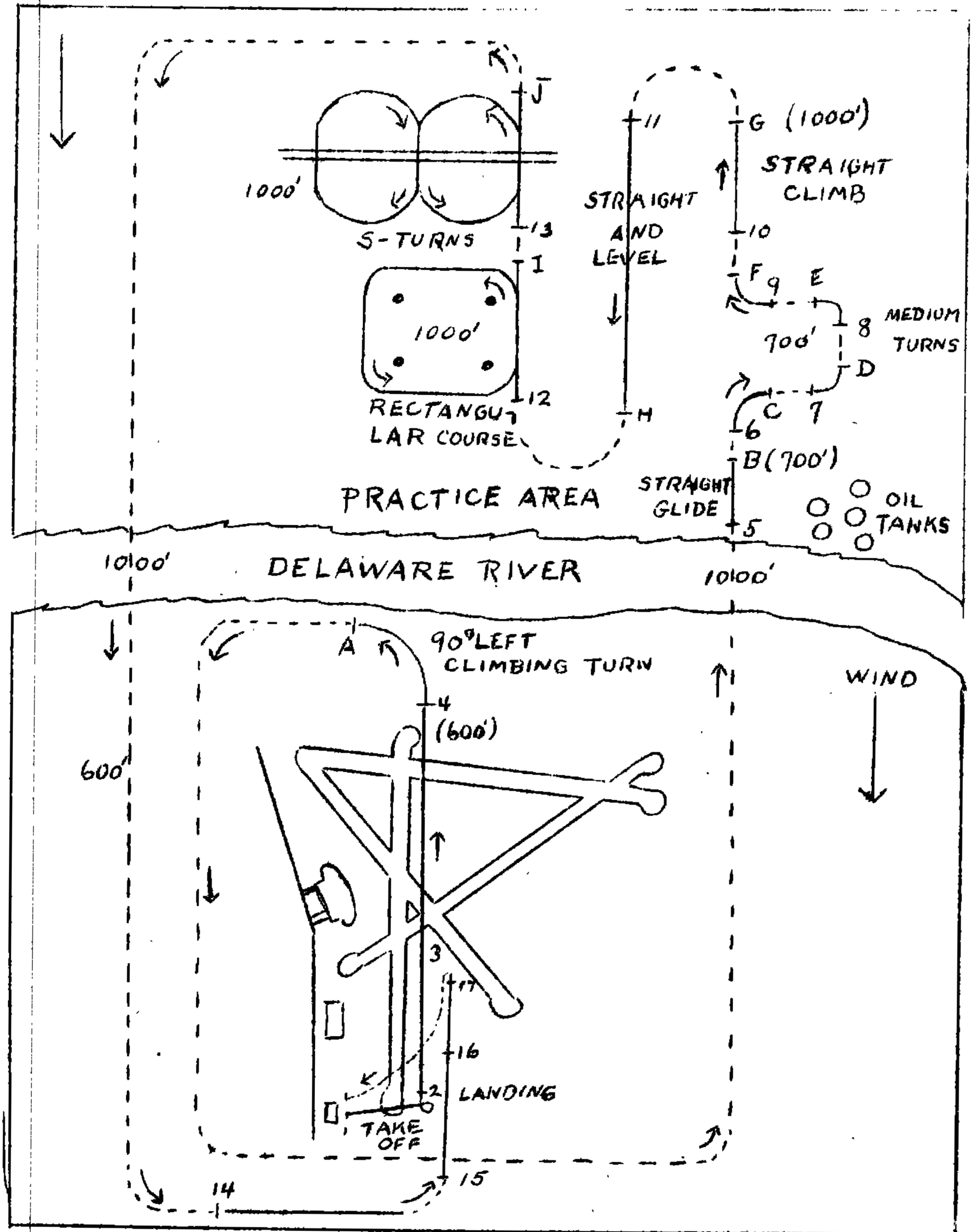
17. PIVOT TURN AND TAXI: to desired position.

For use at: Municipal Airport, Philadelphia, Penna.

STANDARD FLIGHT A

Exhibit 2

(For use at the Municipal Airport, Philadelphia, Penna.)



Prepared by: Morris S. Viteles
Albert S. Thompson
University of Penna.

Exhibit 3

STANDARD FLIGHT B

This flight is designed for use in Stage B and is composed of the maneuvers included in Flight A, with the addition of Power-off Stall and 30° Eights.

The "critical maneuvers", representing those maneuvers which are being studied, are designated by numbers and are capitalized. The intervening maneuvers are "transition maneuvers", representing those maneuvers whose purpose is to get the plane into position for the next critical maneuver.

Order and Description of Maneuvers

1. TAXI: to take-off line plus pivot turn for observation of approaching aircraft and turn back into wind.

2. TAKE-OFF: into wind or as near as appropriate runway allows.

3. STRAIGHT CLIMB: to altitude of 600', attaining optimum climbing speed.

4. 90° LEFT CLIMBING TURN: to 90° angle from take-off direction. This turn should be a long, shallow turn, gradual enough to permit turn into wind in case of engine failure.

   Transition Maneuver A: proceed (around airport, if necessary) to practice area appropriate for the wind direction, attaining altitude of 2000' en route. While flying to practice area make certain that the plane is properly trimmed for straight and level flight. After reaching practice area head into wind in correct position for succeeding maneuver.

5. POWER OFF STALL AND RECOVERY: without use of ailerons.

   Transition Maneuver B: Reduce altitude to 1000' and head into wind, in appropriate location for the succeeding maneuver.

6. STRAIGHT GLIDE: into wind with optimum gliding angle, beginning at 1000' and recovering at 700'.

   Transition Maneuver C: short straight and level flight, at 700', heading into wind.

7. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting into wind and ending in cross-wind direction.

   Transition Maneuver D: short straight and level flight at 700', heading in cross-wind direction.

8. 90° MEDIUM LEFT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

   Transition Maneuver E: short straight and level flight, at 700' altitude, heading into wind.

9. 90° MEDIUM LEFT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting into wind and ending in cross-wind direction.

   Transition Maneuver F: short straight and level flight at 700', heading cross-wind.

10. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

Transition Maneuver G: short straight and level flight at 700', heading into wind.

11. STRAIGHT CLIMB: into wind with optimum climbing angle, starting at 700' altitude and levelling off at 1000'.

Transition Maneuver H: maintaining altitude of 1000', turn down wind.

12. STRAIGHT AND LEVEL FLIGHT: down wind at cruising speed at altitude of 1000', obtaining straight and level flight as soon as possible, maintaining straight and level flight until observer gives signal for next maneuver.

Transition Maneuver I: upon instruction from observer, proceed to correct location for succeeding maneuver, maintaining altitude of 1000'. Ground reference points for rectangular course will be pointed out by observer.

13. RECTANGULAR COURSE: begin into wind, parallel to one side of the rectangular course, and make four turns to left, ending maneuver immediately after fourth turn and when heading straight into wind.

Transition Maneuver J: upon instruction from observer, proceed to correct location for succeeding maneuver, maintaining altitude of 1000'.

14. S-TURNS ACROSS ROAD: begin into wind and make first turn to left. Continue maneuver until two left and two right 180° turns are made, ending maneuver heading into wind.

Transition Maneuver K: proceed to appropriate area and select cross-wind pylons for 30° Eights at altitude of 1000'.

15. 30° EIGHTS: make three complete Eights, maintaining constant distance from pylons during turns.

Transition Maneuver L: upon instruction from observer, return to airport, maintaining altitude of 1000'. Proceed to position appropriate for closing throttle for 180° Side Approach.

16. 180° SIDE APPROACH: close throttle opposite landing spot.

17. FINAL APPROACH AND LANDING: into wind, beginning Final Approach at least 1000' from airport boundary.

18. LANDING RUN: at least 100' without use of brakes.

19. TURN AND TAXI: to desired position.

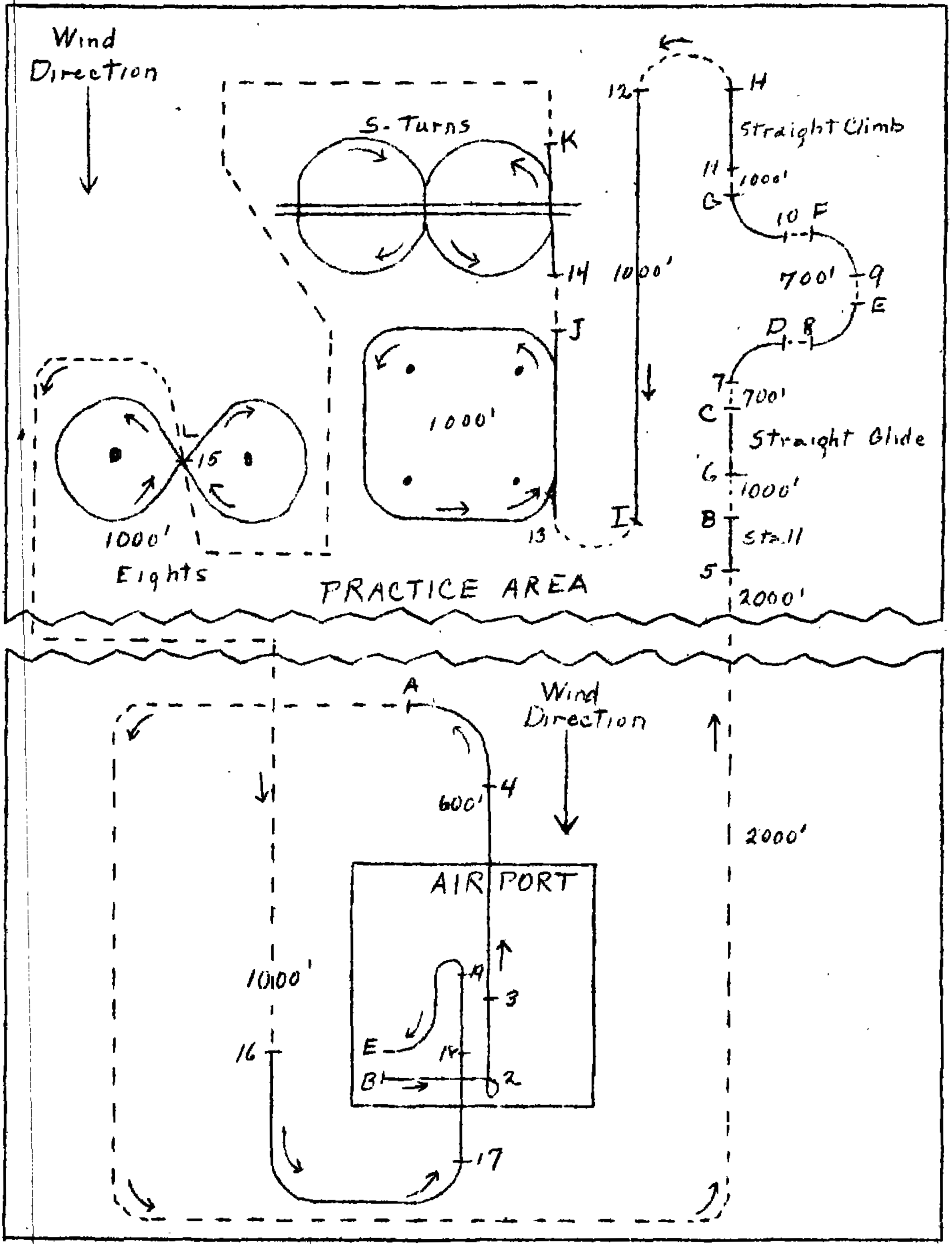
Prepared by: Morris S. Viteles and Albert S. Thompson

For use at: Boston Metropolitan Airport, Norwood, Mass.
Muller Field, Revere, Mass.

11/25/41

STANDARD FLIGHT B

(for use at Boston Metropolitan Airport, Norwood, Mass. and Muller Field, Revere, Mass.)



November 20, 1941

Prepared by: Morris S. Viteles

Exhibit 4

STANDARD FLIGHT C

This flight is designed for use in Stage C and is composed of the maneuvers included in Flights A and B with the addition of 720° Left and Right Power Turns.

The "critical maneuvers", representing those maneuvers which are being studied, are designated by numbers and are capitalized. The intervening maneuvers are "transition maneuvers", representing those maneuvers whose purpose is to get the plane into position for the next critical maneuver.

Order and Description of Maneuvers

1. TAXI: to take-off line plus pivot turn for observation of approaching aircraft and turn back into wind.

2. TAKE-OFF: into wind or as near as appropriate runway allows.

3. STRAIGHT CLIMB : to altitude of 600', attaining optimum climbing speed.

4. 90° LEFT CLIMBING TURN: to 90° angle from take-off direction. This turn should be a long, shallow turn, gradual enough to permit turn into wind in case of engine failure.

Transition Maneuver A: proceed (around airport, if necessary) to practice area appropriate for the wind direction, attaining altitude of 2000' en route. While flying to practice area make certain that the plane is properly trimmed for straight and level flight. After reaching practice area head into wind in correct position for succeeding maneuver.

5. 720° LEFT POWER TURN: at 2000' beginning into wind and attaining 60° bank.

Transition Maneuver B: short straight and level flight after recovery.

6. 720° RIGHT POWER TURN: beginning into wind and attaining 60° bank.

Transition Maneuver C: short straight and level flight after recovery.

7. POWER-OFF STALL AND RECOVERY: without use of ailerons.

Transition Maneuver D: reduce altitude to 1000' and head into wind.

8. STRAIGHT GLIDE: into wind with optimum gliding angle, beginning at 1000' and recovering at 700'.

Transition Maneuver E: short straight and level flight, at 700', heading into wind.

9. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting into wind and ending in cross-wind direction.

Transition Maneuver F: short straight and level flight at 700', heading into cross-wind direction.

10. 90° MEDIUM LEFT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

Transition Manouver G: short straight and level flight, at 700' altitude, heading into wind.

11. 90° MEDIUM LEFT TURN AND RECOVERY : at altitude of 700' and with 45° bank, starting into wind and ending in cross-wind direction.

Transition Manouver H: short straight and level flight at 700', heading cross-wind.

12. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

Transition Manouver I: short straight and level flight at 700', heading into wind.

13. STRAIGHT CLIMB: into wind with optimum climbing angle, starting at 700' altitude and levelling off at 1000'.

Transition Manouver J: maintaining altitude of 1000', turn down wind.

14. STRAIGHT AND LEVEL FLIGHT: down wind at cruising speed at altitude of 1000', obtaining straight and level flight as soon as possible, maintaining straight and level flight until observer gives signal for next manouver.

Transition Manouver K: upon instruction from observer, proceed to correct location for succeeding manouver, maintaining altitude of 1000'. Ground reference points for rectangular course will be pointed out by observer.

15. RECTANGULAR COURSE: begin into wind, parallel to one side of the rectangular course, and make four turns to left, ending manouver immediately after fourth turn and when heading straight into wind.

Transition Manouver L: upon instruction from observer, proceed to correct location for succeeding manouver, maintaining altitude of 1000'.

16. S-TURNS ACROSS ROAD: begin into wind and make first turn to left. Continue manouver until two left and two right 180° turns are made, ending manouver into wind.

Transition Manouver M: proceed to appropriate area and select cross-wind pylons for 60° Eights at altitude of 1000'.

17. 60° EIGHTS: make three complete Eights, maintaining constant distance from pylons during turns.

Transition Manouver N: upon instruction from observer, return to airport, maintaining altitude of 1000'. Proceed to position appropriate for closing throttle for 180° Side Approach.

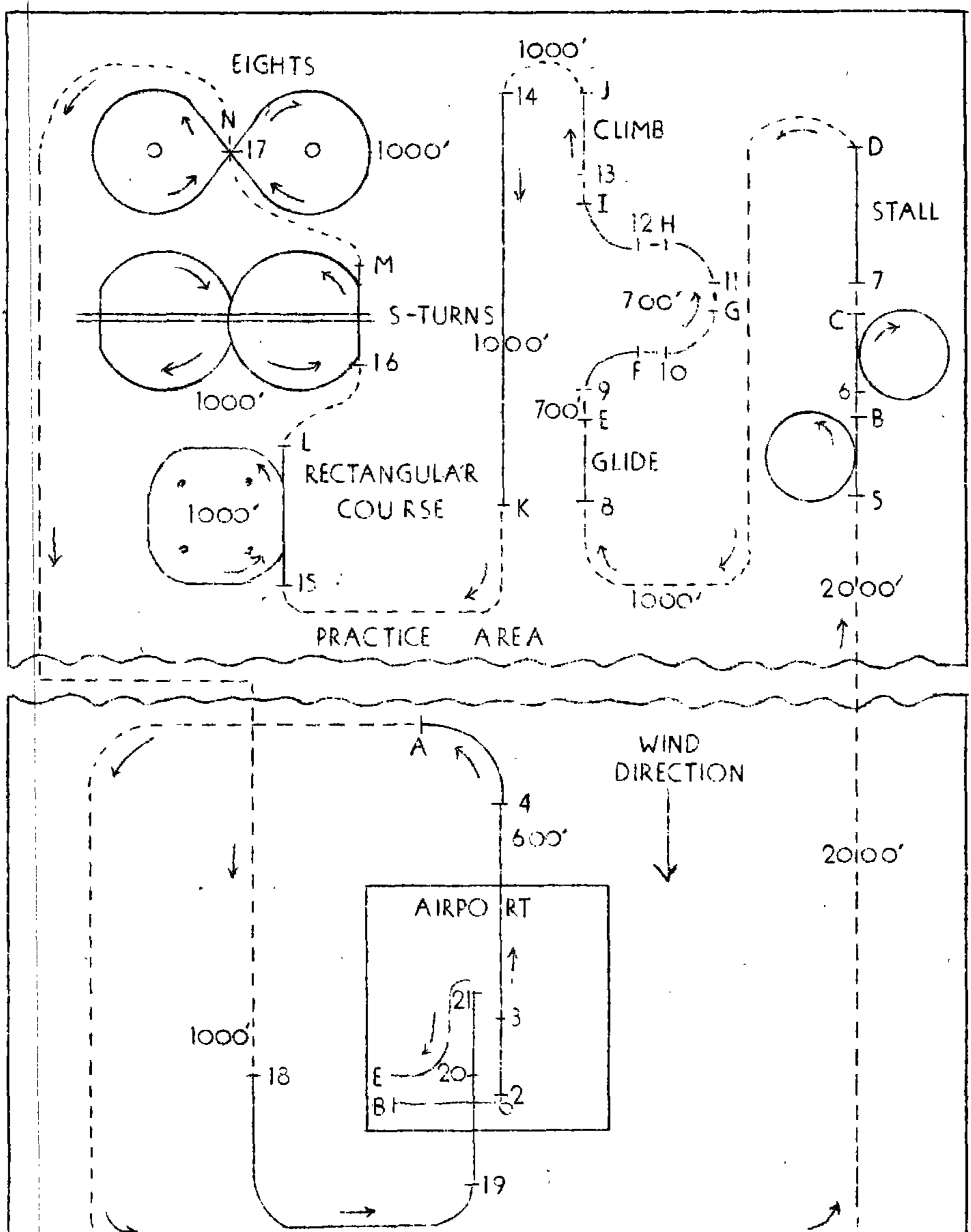
18. FINAL APPROACH AND LANDING: into wind, beginning Final Approach at least 1000' from airport boundary.

19. LANDING RUN: at least 100' without use of brakes.

20. TURN AND TAXI: to desired position.

Prepared by: Morris S. Viteles
Albert S. Thompson
For use at: Boston Metropolitan Airport, Norwood, Mass.
Muller Field, Revere, Mass.

STANDARD FLIGHT C
(for use at Boston Metropolitan Airport, Norwood, Mass.
and Muller Field, Revere, Mass.)



November 20, 1941

Prepared by: Morris S. Viteles
Albert S. Thompson
Univ. of Penna.

Exhibit 5

STANDARD FLIGHT D

This flight is designed for use in Stage D and is composed of the maneuvers included in Flights A, B, and C with the addition of Forward Slip.

The "critical maneuvers", representing those maneuvers which are being studied, are designated by numbers and are capitalized. The intervening maneuvers are "transition maneuvers", representing those maneuvers whose purpose is to get the plane into position for the next critical maneuver.

Order and Description of Maneuvers

1. TAXI: to take-off line plus pivot turn for observation of approaching aircraft and turn back into wind.

2. TAKE-OFF: into wind or as near as appropriate runway allows.

3. STRAIGHT CLIMB : to altitude of 600', attaining optimum climbing speed.

4. 90° LEFT CLIMBING TURN: to 90° angle from take-off direction. This turn should be a long, shallow turn, gradual enough to permit turn into wind in case of engine failure.

Transition Maneuver A: proceed (around airport, if necessary) to practice area appropriate for the wind direction, attaining altitude of 2000' en route. While flying to practice area make certain that the plane is properly trimmed for straight and level flight. After reaching practice area head into wind in correct position for succeeding maneuver.

5. 720° LEFT POWER TURN: at 2000' beginning into wind and attaining 60° bank.

Transition Maneuver B : short straight and level flight after recovery.

6. 720° RIGHT POWER TURN: beginning into wind and attaining 60° bank.

Transition Maneuver C: short straight and level flight after recovery.

7. POWER-OFF STALL AND RECOVERY: without use of ailerons.

Transition Maneuver D: straight and level flight at whatever altitude obtained during recovery from stall.

8. FORWARD SLIP: into wind with 30° left bank, recovering after loss of 300' altitude from beginning of slip.

Transition Maneuver E: reduce altitude to 1000' and head into wind in appropriate position for succeeding maneuvers.

9. STRAIGHT GLIDE: into wind with optimum gliding angle, beginning at 1000' and recovering at 700'.

Transition Maneuver F: short straight and level flight at 700', heading into wind.

10. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting into wind and ending in cross-wind direction.

Transition Manouver G: short straight and level flight at 700', heading into cross-wind direction.

11. 90° MEDIUM LEFT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

Transition Manouver H: short straight and level flight, at 700' altitude, heading into wind.

12. 90° MEDIUM LEFT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting into wind and ending in cross-wind direction.

Transition Manouver I: short straight and level flight at 700', heading cross-wind.

13. 90° MEDIUM RIGHT TURN AND RECOVERY: at altitude of 700' and with 45° bank, starting cross-wind and ending into wind.

Transition Manouver J: short straight and level flight at 700', heading into wind.

14. STRAIGHT CLIMB: into wind with optimum climbing angle, starting at 700' altitude and levelling off at 1000'.

Transition Manouver K: maintaining altitude of 1000', turn down wind.

15. STRAIGHT AND LEVEL FLIGHT: down wind at cruising speed at altitude of 1000', obtaining straight and level flight as soon as possible, maintaining straight and level flight until observer gives signal for next manouver.

Transition Manouver L: upon instruction from observer, proceed to correct location for succeeding manouver, maintaining altitude of 1000'. Ground reference points for rectangular course will be pointed out by observer.

16. RECTANGULAR COURSE: begin into wind, parallel to one side of the rectangular course, and make four turns to left, ending manouver immediately after fourth turn and when heading straight into wind.

Transition Manouver M: upon instruction from observer, proceed to correct location for succeeding manouver, maintaining altitude of 1000'.

17. S-TURNS ACROSS ROAD: begin into wind and make first turn to left. Continue manouver until two left and two right 180° turns are made, ending manouver into wind.

Transition Manouver N: proceed to appropriate area and select cross-wind pylons for 60° Eights at altitude of 1000'.

18. 60° EIGHTS: make three complete Eights, maintaining constant distance from pylons during turns.

Transition Manouver O: upon instruction from observer, return to airport, maintaining altitude of 1000'. Proceed to position appropriate for closing throttle for 180° Side Approach.

19. FINAL APPROACH AND LANDING: into wind , beginning Final Approach at least 1000' from airport boundary.

20. LANDING RUN: at least 100' without use of brakes.

21. TURN AND TAXI: to desired position.

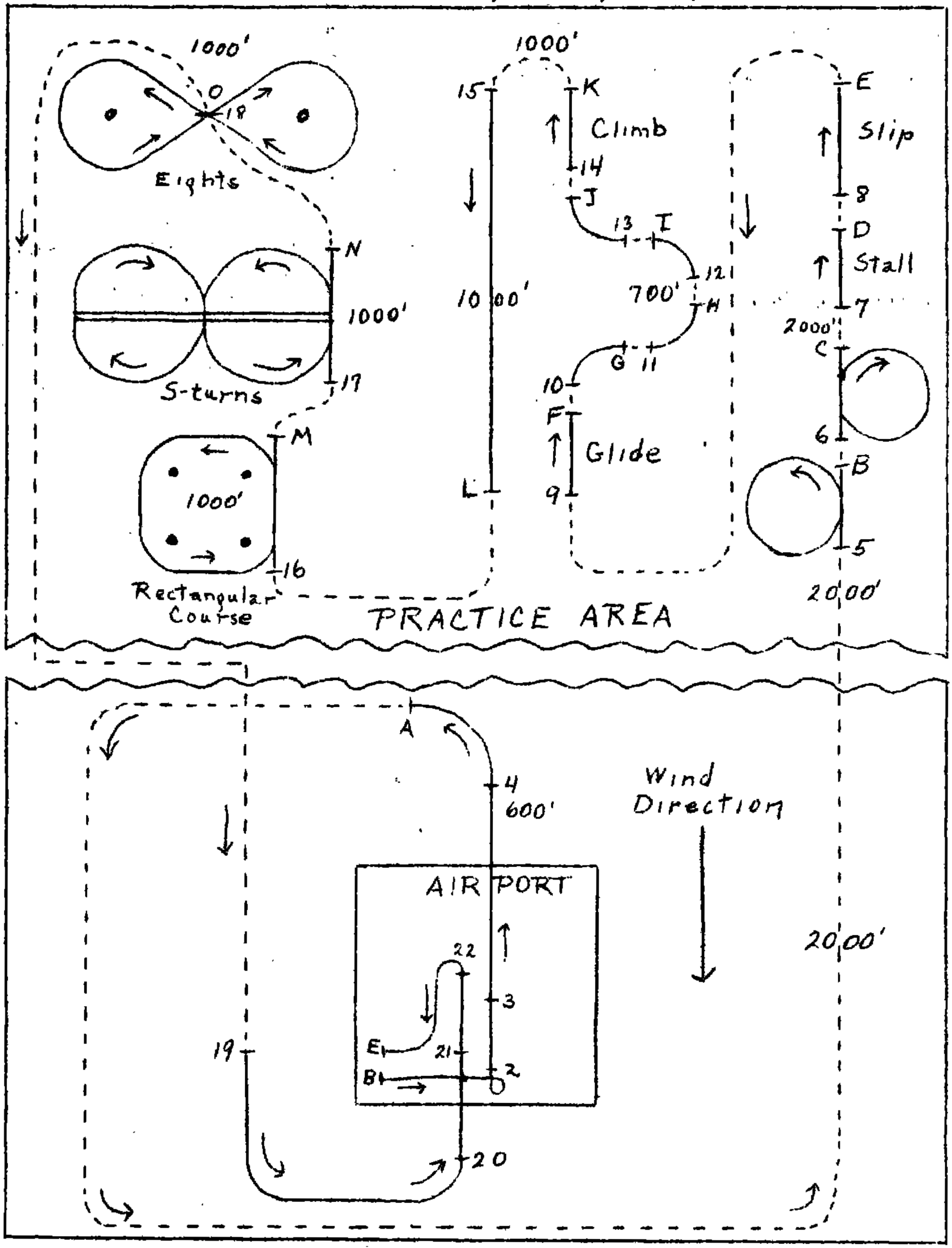
Prepared by: Morris S. Vitoles
Albert S. Thompson

For use at: Boston Metropolitan Airport,
Norwood, Mass.
Muller Field, Revere, Mass.

December 1, 1941.

STANDARD FLIGHT D

(for use at Boston Metropolitan Airport, Norwood, Mass.
and Muller Field, Revere, Mass.)



November 20, 1941

Prepared by: Morris S. Viteles

APPENDIX I

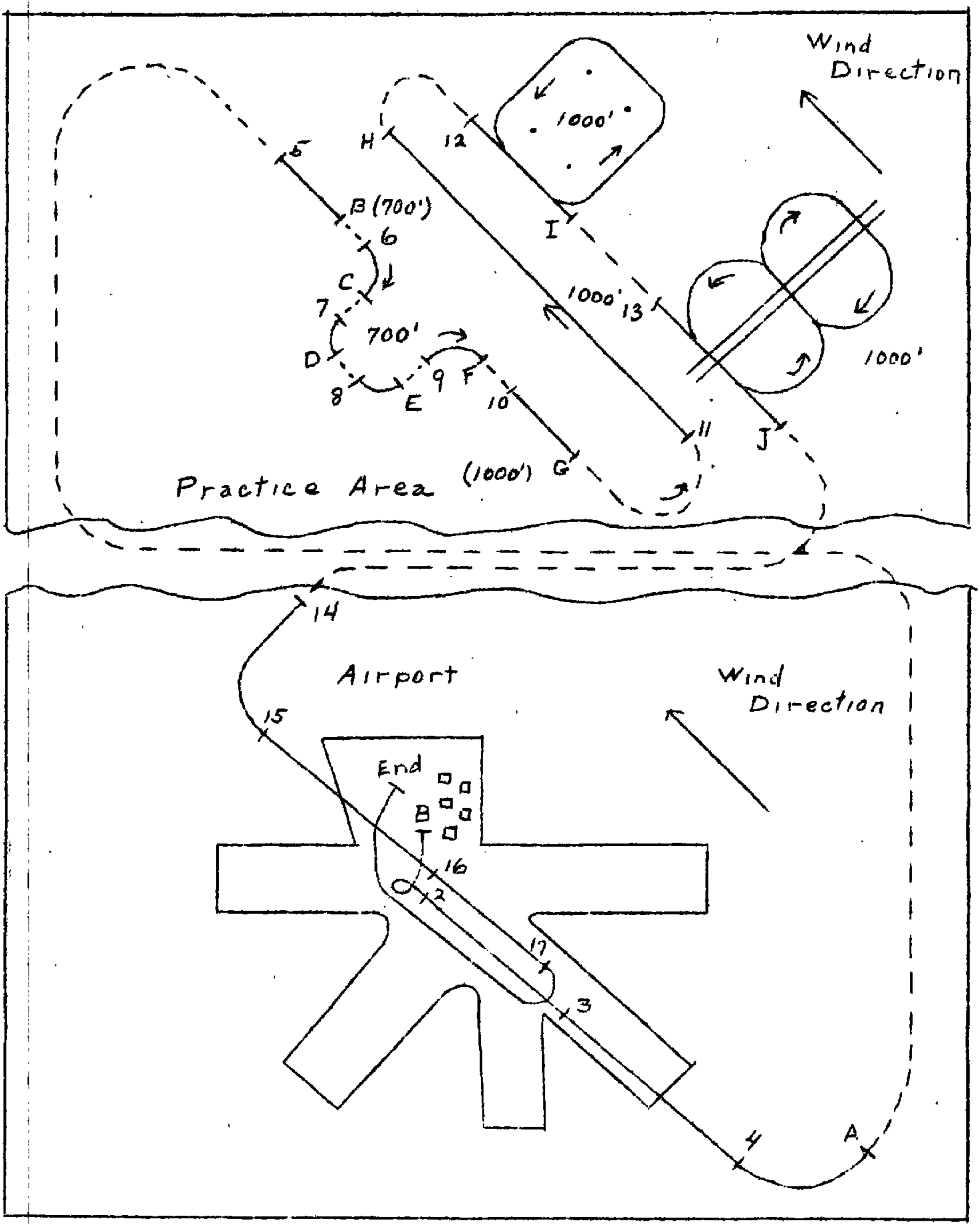
Exhibits A to G

Exhibit A

STANDARD FLIGHT A

(for use at Boston Metropolitan Airport, Norwood, Mass.)

Wind Direction: North

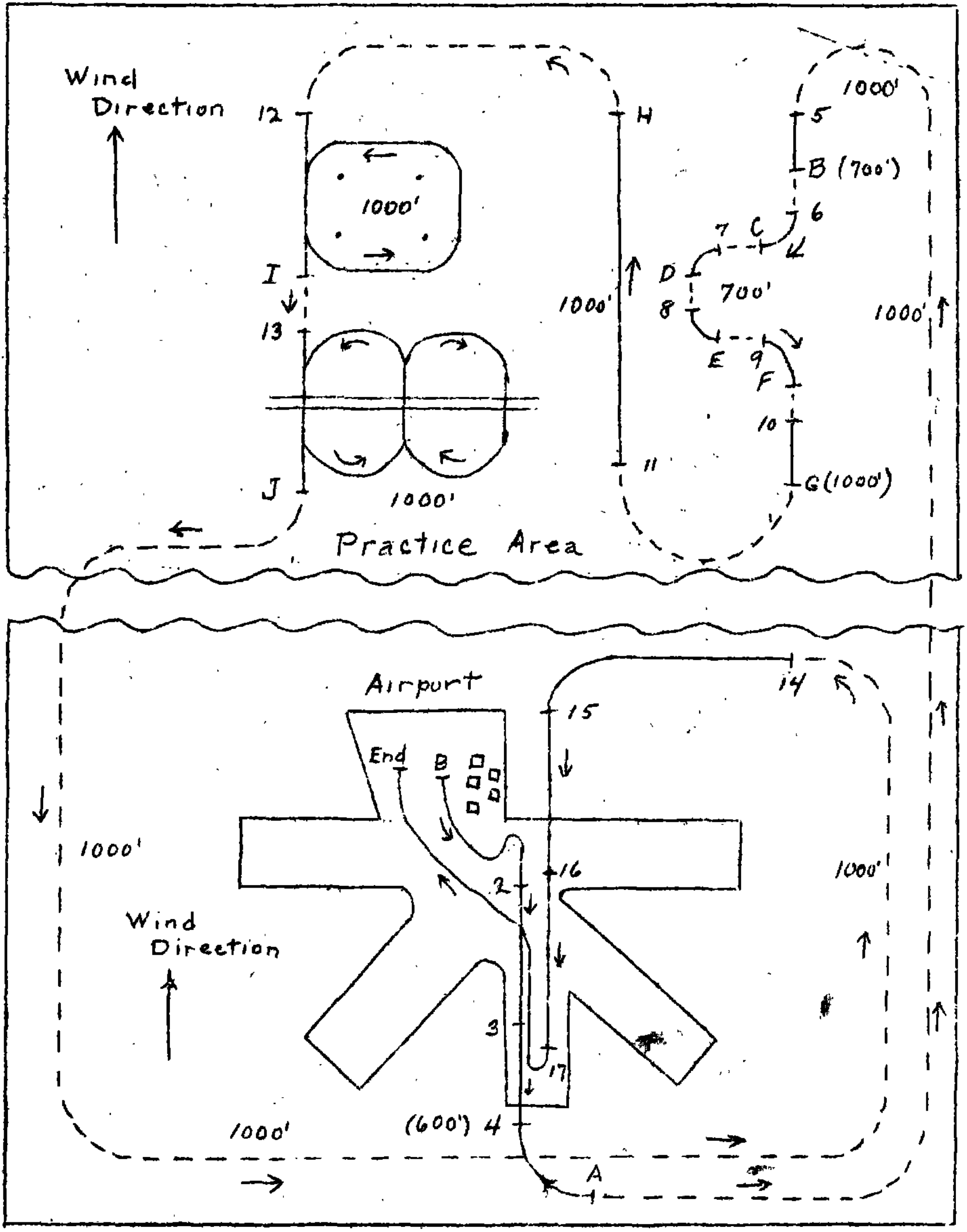


Prepared by: Morris S. Viteles
Albert S. Thompson
Univ. of Penn

STANDARD FLIGHT

(for use at Boston Metropolitan Airport, Norwood, Mass.)

Wind Direction: Northeast



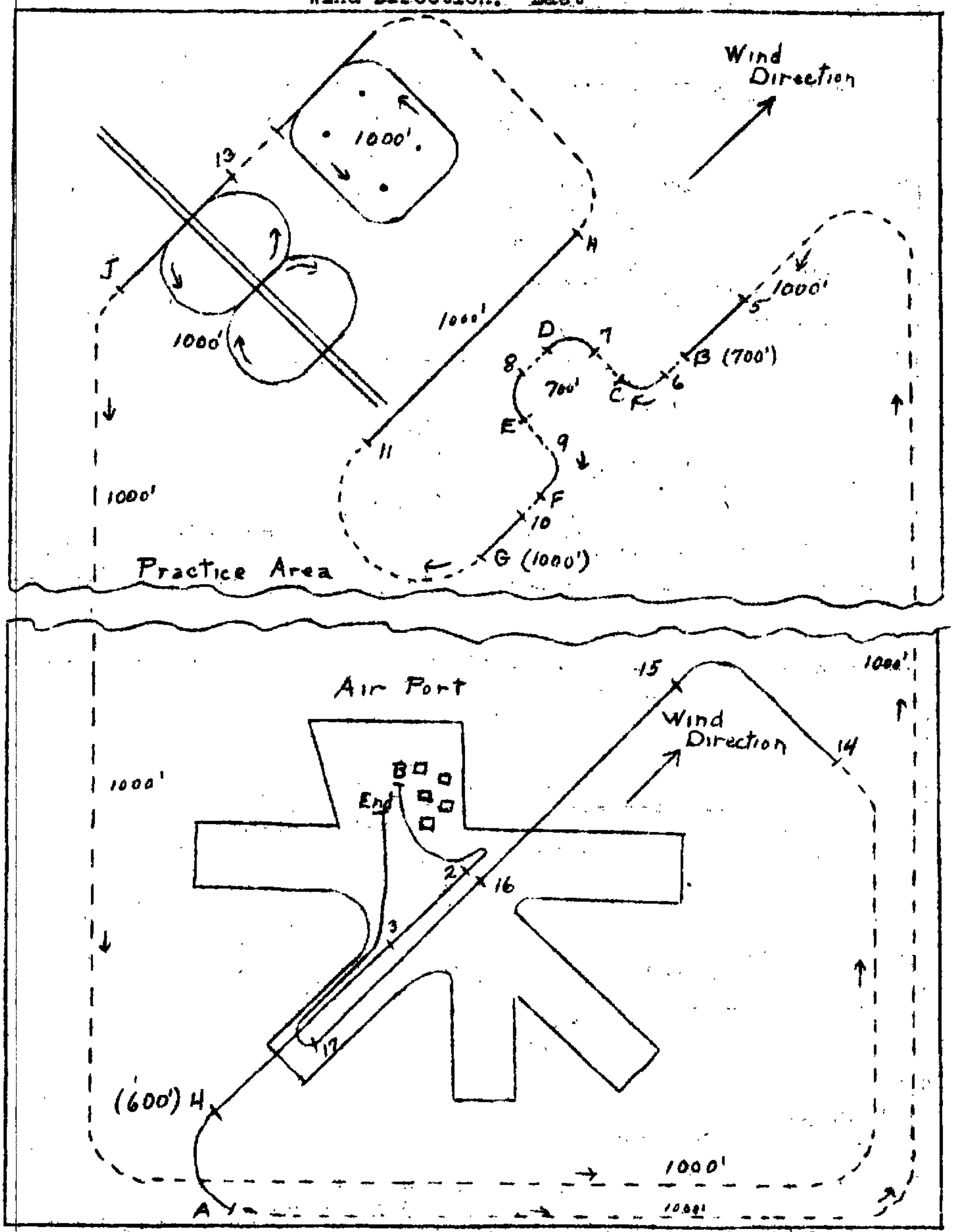
Prepared by: Morris S. Viteles
Albert S. Thompson

Exhibit C

STANDARD FLIGHT A

(for use at Boston Metropolitan Airport, Norwood, Mass.)

Wind Direction: East



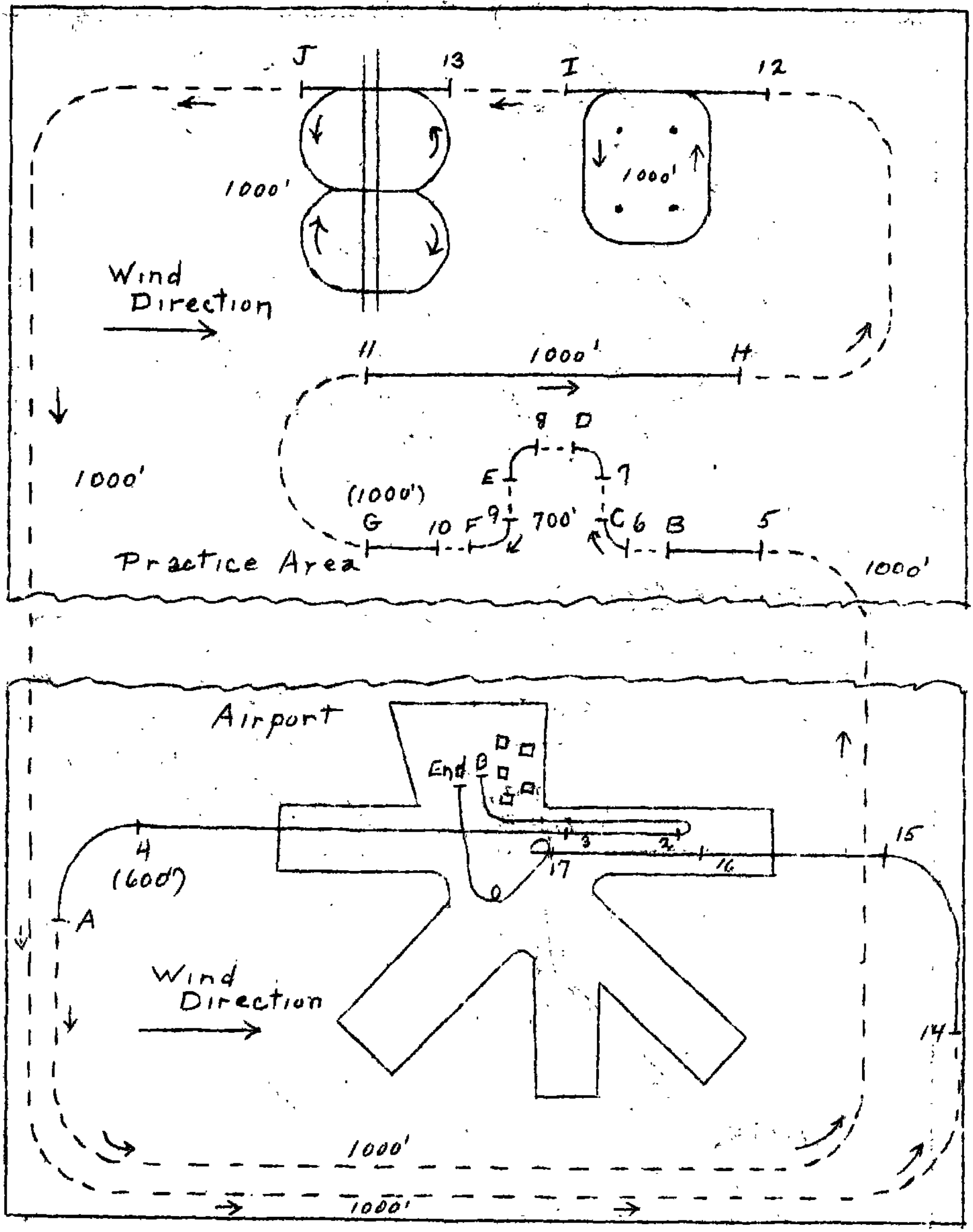
Prepared by: Morris S. Viteles
Alb r Thompso

Exhibit D

STANDARD FLIGHT A

(for use at Boston Metropolitan Airport, Norwood, Mass.)

Wind Direction: Southeast



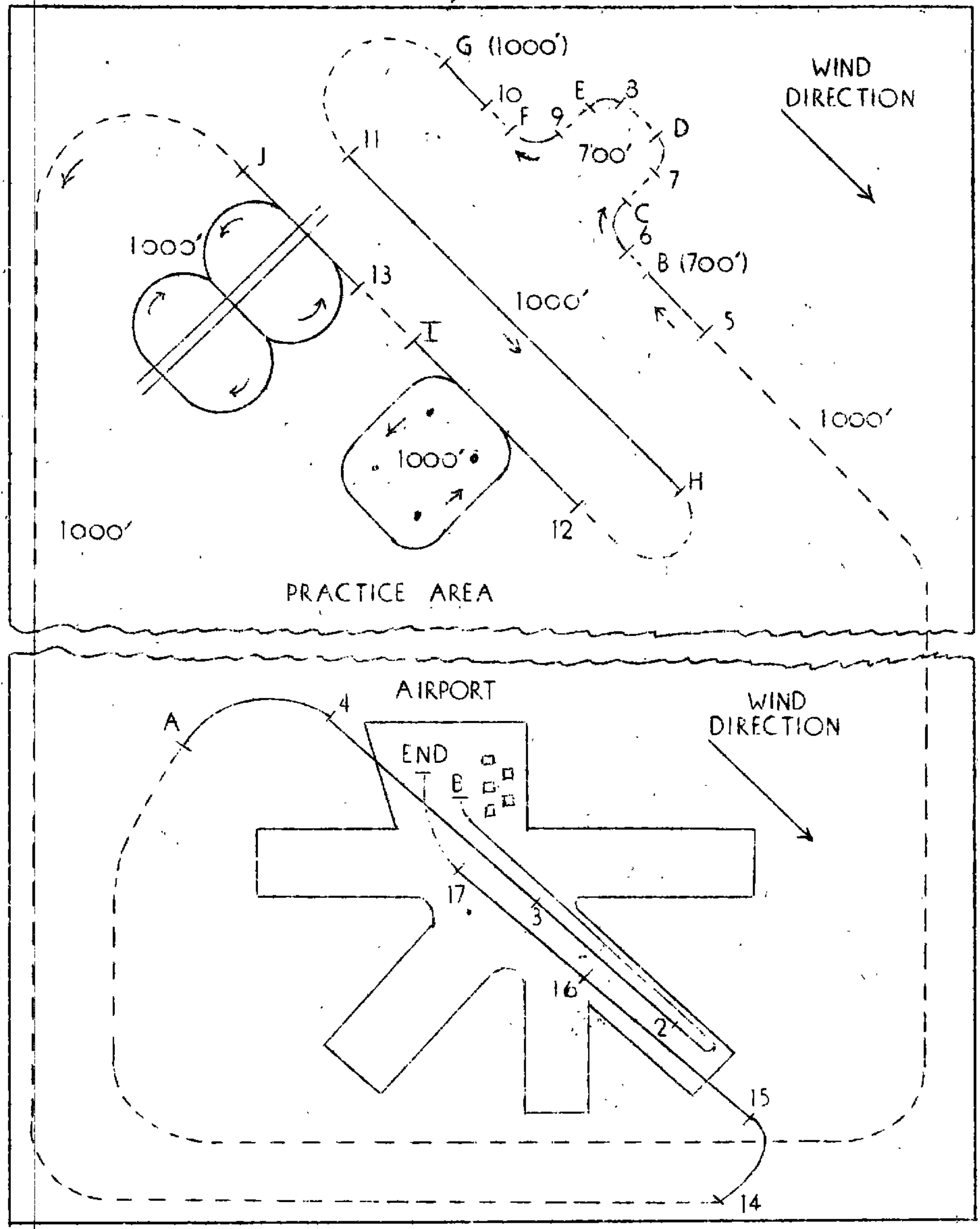
Prepared by: Morris S. Viteles
Albert S. Thompson
Univ. of Penna.

Exhibit [illegible]

STANDARD FLIGHT A

(for use at Boston Metropolitan Airport, Norwood, Mass.)

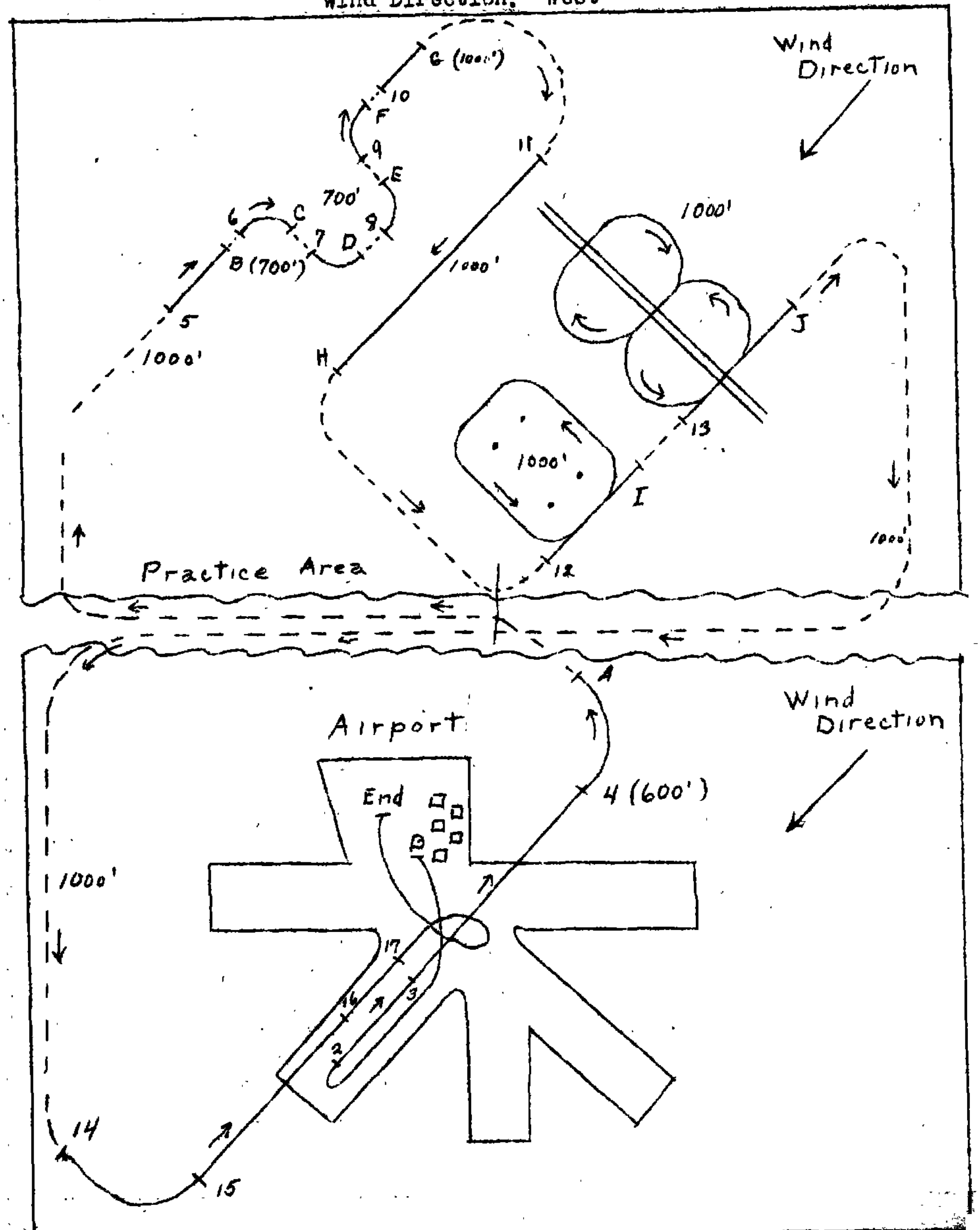
Wind Direction: South



Prepared by: Morris S. Viteles
Albert S. Thompson
Univ. of Penna.

STANDARD FLIGHT A
(for use at Boston Metropolitan Airport, Norwood, Mass.)

Wind Direction: West



Prepared by: Morris S. Viteles

STANDARD FLIGHT A

(for use at Boston Metropolitan Airport, Norwood, Mass.)

Wind Direction: Northwest