National Research Council

Committee on Selection and Training of Aircraft Pilots

Executive Subcommittee

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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

February 17, 1943

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

Dear Dr. Brimhall:

In a study sponsored by the Committee on Selection and Training of Aircraft Pilots, Dr. Joseph Tiffin and Dr. John Bromer, of Purdue University, have compared the eye movements of experienced and inexperienced pilots. The results of their investigation are presented in the attached report, entitled Analysis of Eye Fixations and Patterns of Eye Movement in Landing a Piper Cub J-3 Airplane. This 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 authors adapted techniques of motion-picture photography of eye movements to the specific conditions of the Piper Cub J-3 airplane, and introduced an ingenious device for indicating on the film the height of the plane during the last few seconds before landing.

In spite of the fact that this is an exploratory investigation, certain general trends are to be observed in the findings. For example, while individual pilots exhibited a fair degree of consistency in visual habits, no single pattern was discovered which invariably differentiates experienced and inexperienced pilots. Moreover, the authors also noted that "experienced pilots who insisted that there was a proper place to look in the landings were likely to deviate from this suggested pattern in their own landings." This finding has a particularly interesting bearing on training practices.

Although such findings and conclusions are reported, it must nevertheless be stressed that this represents only an exploratory study. In an extension of the investigation, records covering longer periods of time would be desirable. The visual field might well be divided into smaller sectors than those considered in the study. Vertical as well as lateral displacements could profitably be analyzed. The number of cases and conditions of the experiment should be adequate to provide evidence on the reliability of both the sampling and the technique of reading and interpreting the records. It would also be desirable to isolate eye movements from head movements, especially in view of differences of opinion with respect to the advisability of using primarily eye movements or combined head and eye movements in landing a plane.

Techniques for measuring interpupillary distances in successive frames, to estimate the distance of objects fixated in the visual field, might also be used.

The present study has produced such outcomes as might reasonably be anticipated from a preliminary investigation. It also reveals avenues of research which can be profitably followed with a view of gathering conclusive facts that can be extremely useful in a practical program of pilot training.

Very truly yours,

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

MSV:rm

Editorial Foreword

It is commonly recognized that landing is one of the critical maneuvers in the safe operation of a plane. A question of extreme importance, in considering accuracy and safety in landing, is the nature of the eye movements which take place in approaching the field and in landing.

The importance of this problem was recognized by the Division of Research of the Civil Aeronautics Administration and the National Research Council Committee on Selection and Training of Aircraft Pilots. As early as 1939, studies of eye movements in landing were undertaken by Dr. Brian O'Brien, of the University of Rochester, and in 1940 Dr. Carl Pfaffmann, of Brown University, initiated a study in the same field, with the aid of funds allotted by the Committee on Selection and Training of Aircraft Pilots. Dr. Pfaffmann's investigation included an introspective study of visual cues employed in landing a plane. He also gathered statements from instructors and introspective reports by psychologists who had received flying training.

On the basis of his own introspections, summarized in a Supplement to the attached report, Dr. Pfaffmann reached the conclusion that it is not possible to emphasize too much the importance of momentary fixations along the ground, to the side of the plane, during the last part of the landing maneuver. On the basis of his investigations he also felt free to predict that "I should expect photographs of head and eye movements taken during the landings to show a series of eye fixations with the angle of gaze directed slightly to one side and downward."

The results of studies made by Dr. O'Brien are not yet ready for publication. Unfortunately, Dr. Pfaffmann was unable to complete the work sponsored by the Committee and discussed in the Progress Reports embodied in the Supplement. In the meantime, Dr. Joseph Tiffin and Dr. John Bromer undertook an exploratory investigation of eye fixations and patterns of eye movement during landing a Piper Cub J-3 airplane. The results of this study are embodied in the attached report. It is of interest to note that these verify, to some extent, the prediction made by Dr. Pfaffmann, on the basis of his preliminary investigations, and indicate, as well, possible directions for further research.

ANALYSIS OF EYE FIXATIONS AND PATTERNS OF EYE MOVEMENT IN LANDING A PIPER CUB J-3 AIRPLANE

Summary

Motion pictures of the eye-movement patterns of pilots during the last 5-10 seconds before landing were analyzed to determine whether certain of them were characteristic of the skilful pilot.

Photographs were taken of the pilot's eyes at the rate of 16 frames per second with a camera specially mounted in a Piper Cub J-3. Three flashlight bulbs on the pilot's headgear were activated in turn by a device which measured the distance from the ground and indicated the exact time at which the wheels first touched.

The pictures were studied first in normal projection and later by a detailed frame-by-frame analysis. Graphs of the eye movements of 33 pilots were made for a total of 177 landings. These graphs show the movements in 7 different visual fields as determined by the windows of the plane. The graphs are separated into four groups according to the flight experience of the pilot.

Analysis of the data reveals that the experienced pilots exhibit no single general pattern of eye movement. On the other hand, individual pilots show a certain amount of consistency in their own patterns of movements while landing. Another tendency revealed by the graphs is the tendency of many pilots to spend a certain portion of the last five seconds in looking directly toward the front of the ship.

It is concluded that there are no clear-cut differences between the eye-movement patterns of the experienced and inexperienced pilots. Experienced pilots, however, show back-and-forth excursions until the last five seconds before landing. Inexperienced men do not all show these. Some of the experienced pilots continue excursive movements during the last five seconds before landing, while other experienced pilots tend to settle down to one area, looking to the right or left, but not alternately between right and left. The settling occurs either in the forward area, representing 12° of vision, or in the adjoining large area representing 54°. Either one of these two areas on either side of the plane seems about equally likely to serve the pilot's visual purposes. Settled fixation just before landing seems never to occur at right angles to the axis of the ship.

It is recommended that instructors do not insist that students learn to look at a certain specified place, and nowhere else, while the airplane is being landed.

Analysis of Eye Fixations and Patterns of Eye Movement in Landing a Piper Cub J-3 Airplane

The present research has been done in order to study the different types of eye fixations and eye-movement patterns that occur during the landing of an airplane by pilots with varying degrees of skill. The scope has been that of a preliminary investigation.

PROCEDURE

Throughout this study all observations have been made in a single type of airplane -- the Piper Cub J-3. The head and eyes of the pilot have been photographed with a motion-picture camera throughout the last 5 to 10 seconds before the landing. The landing has been defined as the moment at which any part of the airplane touches the ground. The pilot was always in the rear seat of the plane, which has a tandem arrangement. The camera, an 8-mm. Cine-Kodak, was mounted above the instrument panel on a support attached to the front braces of the cabin. (See Figure 1.) It was directly in front of the pilot and slightly above the level of his head. An observer, who rode in the front seat of the plane, operated the camera.

In order to determine roughly the altitude of the plane during the last few seconds before landing, a piece of fishing pole about 8 feet long was attached to the center of the wheel assembly of the plane. (See Figure 2.) When the plane was in flight, this rod was kept almost vertical by a spring and a piece of metal plate attached to the butt of the pole, which served to counter-balance the wind resistance exerted on the long end of the lever. As the plane descended close to the ground the pole was bent backwards at an angle making contact successively with 3 copper points. These contact points closed the circuit between a pair of flashlight batteries and 3 flashlight bulbs which were mounted on a special plate attached to the pilot's headgear and worn on his forehead. The pole was almost vertical during normal flight, but in the glide, because of the loss of blast on the balance plate from the propeller, the pole was tilted backwards at an angle of about 30° and contact was thus made at the first point. Contact at the second point occurred when the wheels of the plane were about 4 feet from the ground, and the third light went on within one second of the time that the wheels actually touched the ground. On the film, the actual time of landing was determined by reference to these lights and also to the blur which invariably occurred at the landing because of the jarring of the airplane and the camera.

The moving pictures were taken at 16 frames per second. These pictures made possibly an analysis of the sequence of visual fixations of the pilot during the time the camera was in operation. Since the lights controlled by the fishing pole were located on the forehead of the pilot, the sequence of visual fixations could be related approximately to the altitude of the airplane.

Each sequence of picture records was studied carefully; first, by motion-picture projection and, second, by slow and detailed frame-by-frame projection. The normal motion-picture projection gave a better integrated representation of the visual pattern; the frame-by-frame analysis made it possible to detect glances of short duration and to classify the sequence of fixations.

The reliability and validity of this method of studying visual fixations have been investigated by Karslake,[1] and the method has been used by McNamara[2] in an investigation of eye-movement behavior in looking at advertisements.

Karslake found the technique to yield essentially the same results with regard to sequence of glances when different film readers interpreted the films. The correlations between different film-readers in their readings of sequences of glances varied from .96 to .99. Inasmuch as the angular variations in glances were smaller for the subjects looking at advertisements who were studied by Karslake than for the pilots who were studied in the present investigation, it is reasonable to conclude that the present use of the method has at least as high a reliability as that reported by Karslake.

In making the frame-by-frame analysis the direction of every glance was recorded on a specially prepared chart on which the available visual area to the pilot was broken down into 7 areas. (See Figure 3.) The angular area subtended by each of the seven visual areas is indicated in the scale drawing shown in Figure 4.

In the Piper J-3 airplane there are three window sections to the left and three to the right of the pilot in the rear seat. These are used with slight modification as sub-areas of vision; the seventh includes the entire space of the windshield. This definition of the visual area was in terms of horizontal areas only. No attempt to analyze the vertical direction of the glances was made for the following reasons:

1. Because the attitude of the airplane cannot be detected by the method used in the investigation, an analysis of the vertical direction of the visual axis in terms of the part of the window looked through was not very meaningful.

2. In the Piper Cub there is a limited vertical range of vision.

3. An analysis of the results shows that a consistent relationship existed between the lateral direction of glances and the distance from the plane the pilot was looking. When the camera was first turned on, the plane was usually still in its normal glide; thus, glances through the windshield afford a view of the ground. As the plane levels out, however, the pilot is unable to see the ground at all through the windshield and because of the construction of the windows the distance which the pilot can look at the ground ahead of him is limited by the window section through which he looks. As he looks out through the front section of either side his eyes of necessity sweep some distance ahead of the plane. To observe the ground nearby, he must rotate his eyes further to the side as well as downward. Therefore during the last 5 seconds before the landing, the distance the pilot is looking can be estimated by the window section through which he is looking. (The lower half of the window sections, it follows, are the effective portion during landing.)

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[1] J. S. Karslake. The Purdue Eye-Camera: A Practical Apparatus for Studying the Attention Value of Advertisements, Journal of Applied Psychology, XXIV (1940) pp. 417-440.

[2] J. J. McNamara. A New Method for Testing Advertising Effectiveness through Eye-Movement Photography, Psychological Record, IV (1941), pp. 399-460.

Figure 1. Camera Mounting Used In Pilot Eye Pattern Investigation.

Figure 2. Fishing Pole Arrangement Which Indicates Altitude of Landing Plane.

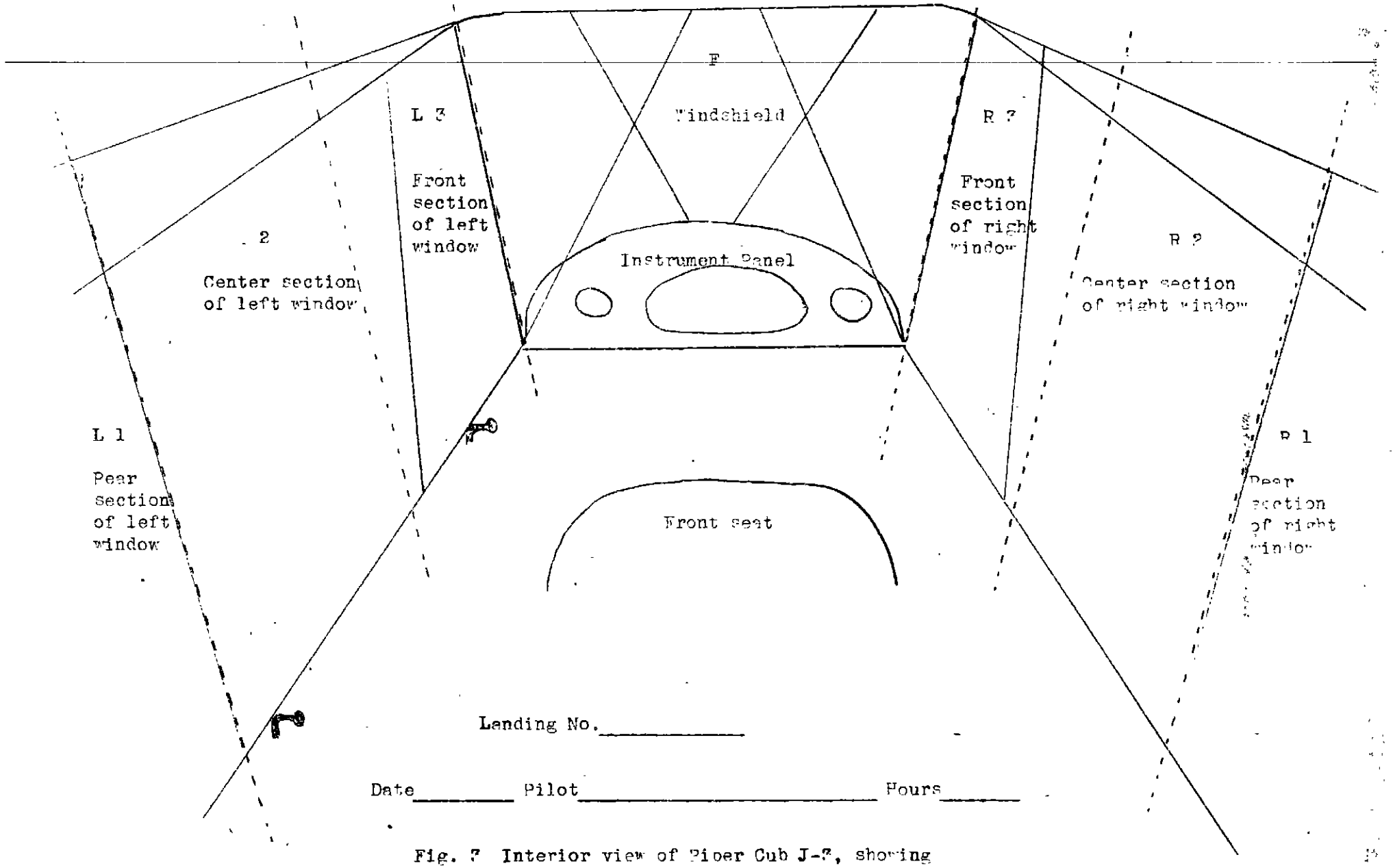


Fig. 7 Interior view of Piper Cub J-3, showing seven visual areas designated in eye-movement records of landings.

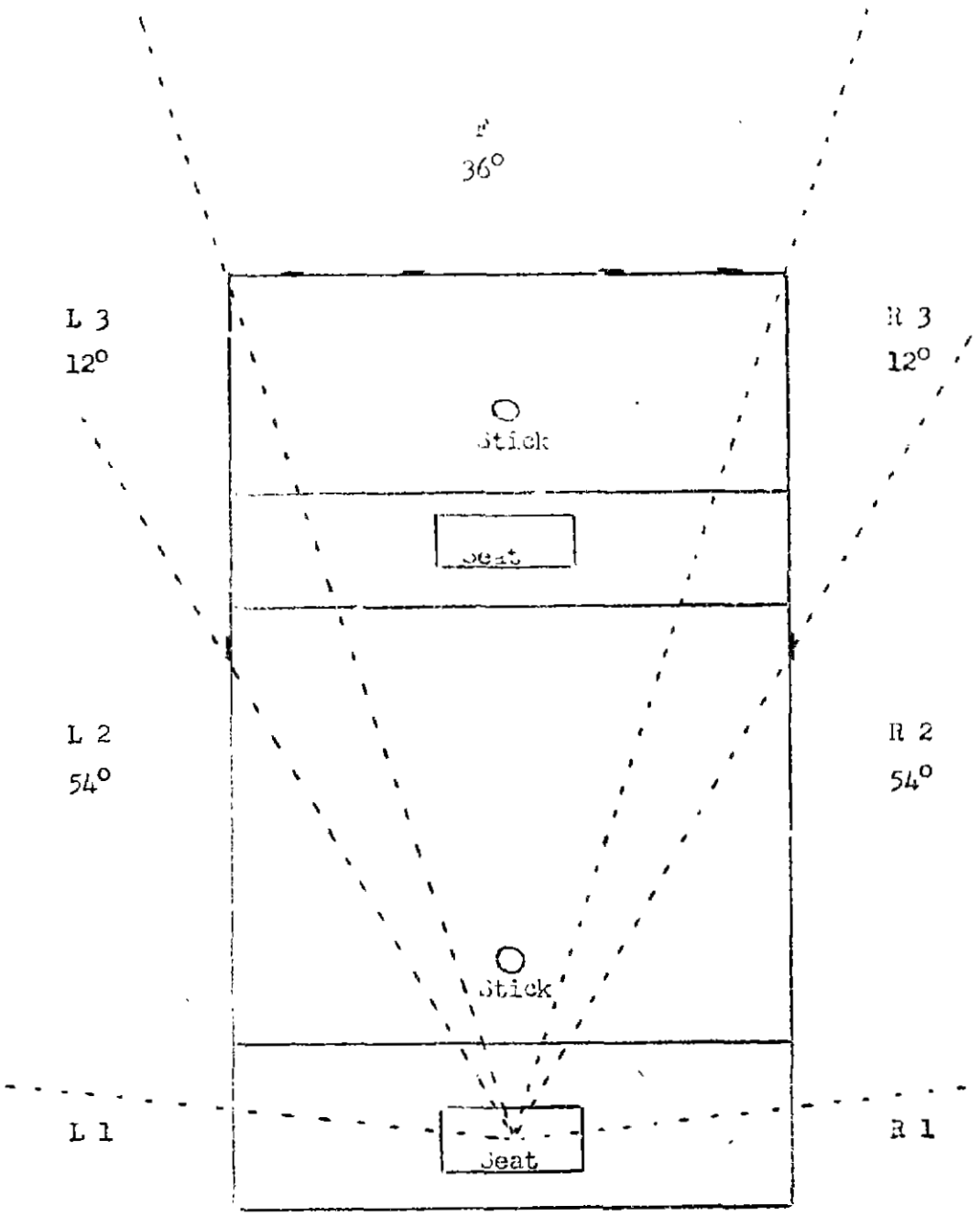


Fig. 4 Top view of Piper J-3 cabin, showing angles of different views used in study of eye-movements and patterns of movement used in landing.

Scale: 1/8 actual size

F

R 3

L 3

R 2

L 2

R 1

L 1

Fig. 5. Illustrations of the views of a pilot's face and eyes as he is looking in each of the seven areas designated in Figs. 3 and 4.

A B

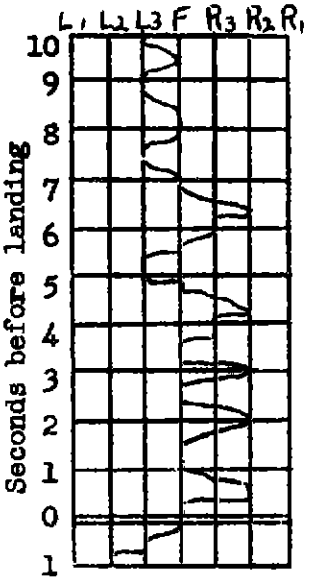
Fig. 6. Enlargements from movie film taken during a landing. In "A" the pilot is looking out the front of the cabin (F in Fig. 3); in "B" the pilot is looking out the area to the left of front (L 3 in Fig. 3).

An illustration of the view of the pilot's face as photographed when he is looking in each of the seven fixation areas is shown in Figure 5. These pictures were taken as "stills" while the subject photographed was looking in each of the areas indicated on Figure 4.

Enlargements of two frames from an actual film made during the study are shown in Figure 6. In "A" the pilot is looking front - "F" - and in "B" he is looking in the area "L-3" (see Figure 4).

After the complete frame-by-frame records of the direction of the eyes had been made for each landing, the data for each landing were transferred to a time record showing the sequence of glances in each of the seven visual areas. This gave a graphical representation of the temporal pattern of glances.

The graphical representation of one of these time records is illustrated below:



The seconds before the landing are indicated by the horizontal lines above the double line. The double line indicates the moment of the landing, and the single horizontal line below the double line indicates the second of time immediately following the landing. The lateral measurements indicate the position of the eyes at various points before, during, and for one second after the landing. The positions at the top of the drawing (L_1, L_2, L_3, F, R_3, R_2, and R_1) correspond to the window and angular areas designated with corresponding symbols on Figures 3 and 4. Graphic plots of all landings studied were made and are attached to the present report. These records were analyzed to determine whether there was any consistent pattern among experienced pilots, whether there were fairly consistent differences between experienced and inexperienced pilots, and whether there were differences with the same pilot for good and poor landings.

Pictures were taken of 177 landings made by 33 pilots. The pilots used in the investigation were classified as follows: Seven were in the elementary stage of dual instruction, i.e., before the solo; five had soloed but had not obtained the private certificate; eight had secured their private licenses but had flown less than 200 hours; and 13 had 200 hours or more of flying experience. From one to eight landings were photographed for each pilot, except for two pilots with a few solo hours at the beginning of the experiment who were followed through about five hours of landing practice.

RESULTS

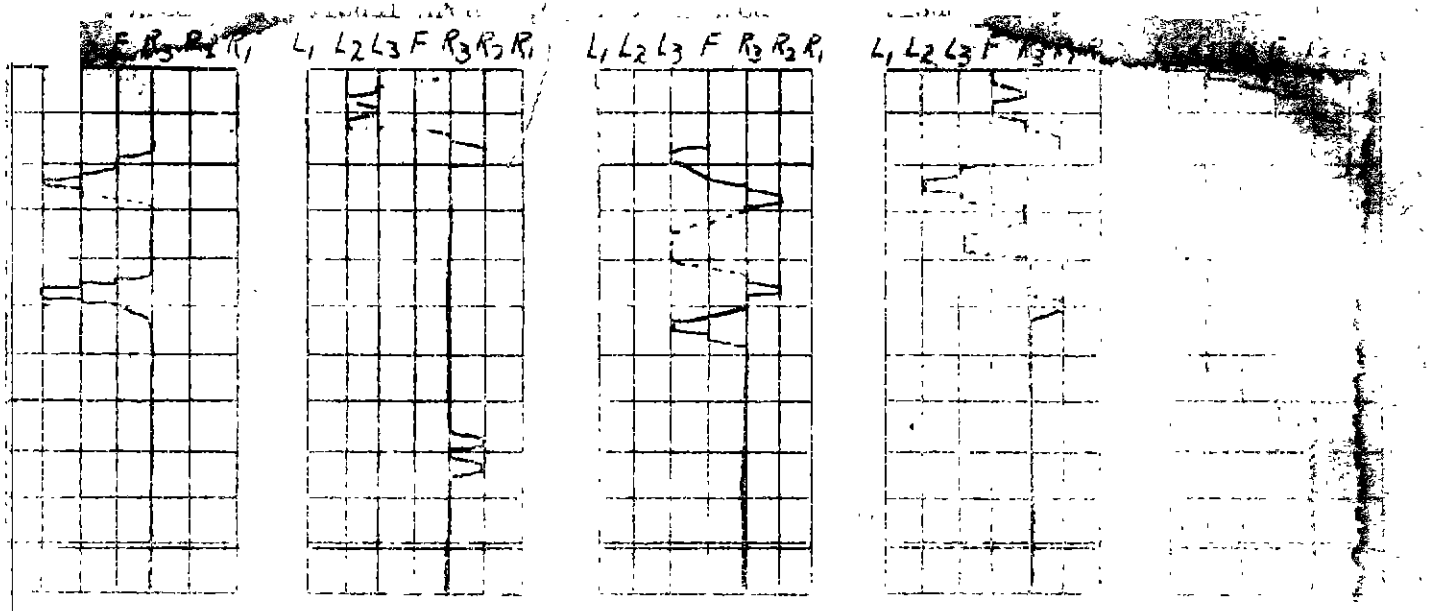
As mentioned previously, the landings were divided for study according to the flying hours of experience of the pilots. The division of pilots according to hours of flying is based on the assumption that such a division will result in an at least approximate classification according to skill in landing.

It is possible (or even probable) that a better criterion would have been available if it had been possible to grade each landing objectively, regardless of the flying hours of the pilot who made it. An attempt was made to so classify or grade each landing (and these ratings, when available, are indicated under each of the graphic records included at the end of this report), but for several reasons these ratings were found to be of limited value. Some pilots regard a landing made "3 feet in the air" as a very bad landing. Others, who have been trained in a different school, regard such a landing as even better than one in which the airplane stalls just as it touches the ground. Also the landings were made under quite varied weather conditions. "Good landings" in a steady 10-mile wind were somewhat more frequent than "good landings" in gusty weather or in an 18-mile gale, even when made by pilots of presumably equal skill, or even by the same pilot. The soundest procedure therefore seemed to be a classification of the landings according to the experience of the pilots, rather than on an individual rating of each landing.

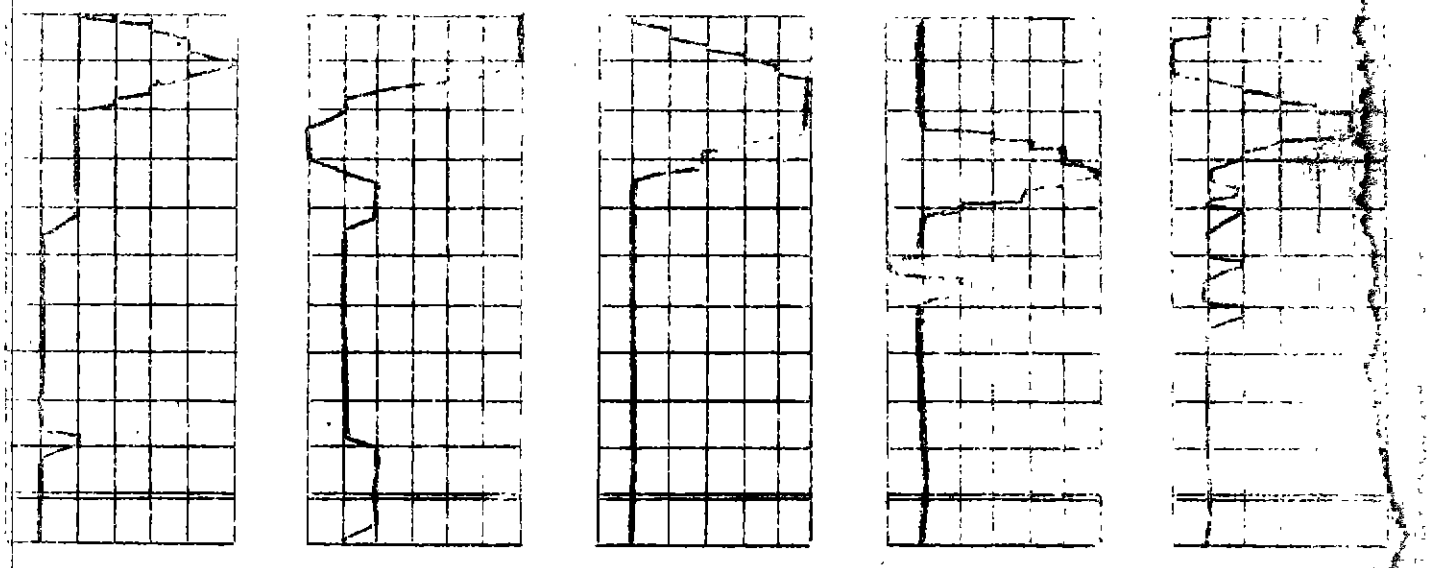
Frame-by-frame analysis of the records. Figure 7 shows 15 illustrative graphic records of eye fixations during landings (five for each of three experienced pilots) and Figure 8 shows 8 additional records for two inexperienced pilot (5 for one and 3 for another). These graphs may be interpreted as previously described. Thus the first landing graphed for J. Stair, Sr. shows that in the temporal interval between 8 seconds and 4.5 seconds preceding the landing, two visual excursions were made between areas L_2 and R_3, while the remainder of the time before (and at least until one second after) the landing was spent looking in area R_3.

Perhaps the most obvious conclusion suggested by the results shown graphicall in the set of charts such as are illustrated in Figures 7 and 8 is that there is no single general pattern of eye movement which holds for all or even most experienced (and presumably skilled) pilots. There is also no consistent tendency to use fewer movements, or more movements, as flying experience increases. An observer who did not know the pilots used in this study would have trouble in differentiating between pre-solo students and pilots with 5000 hours of flying time on the basis of eye-pattern records.

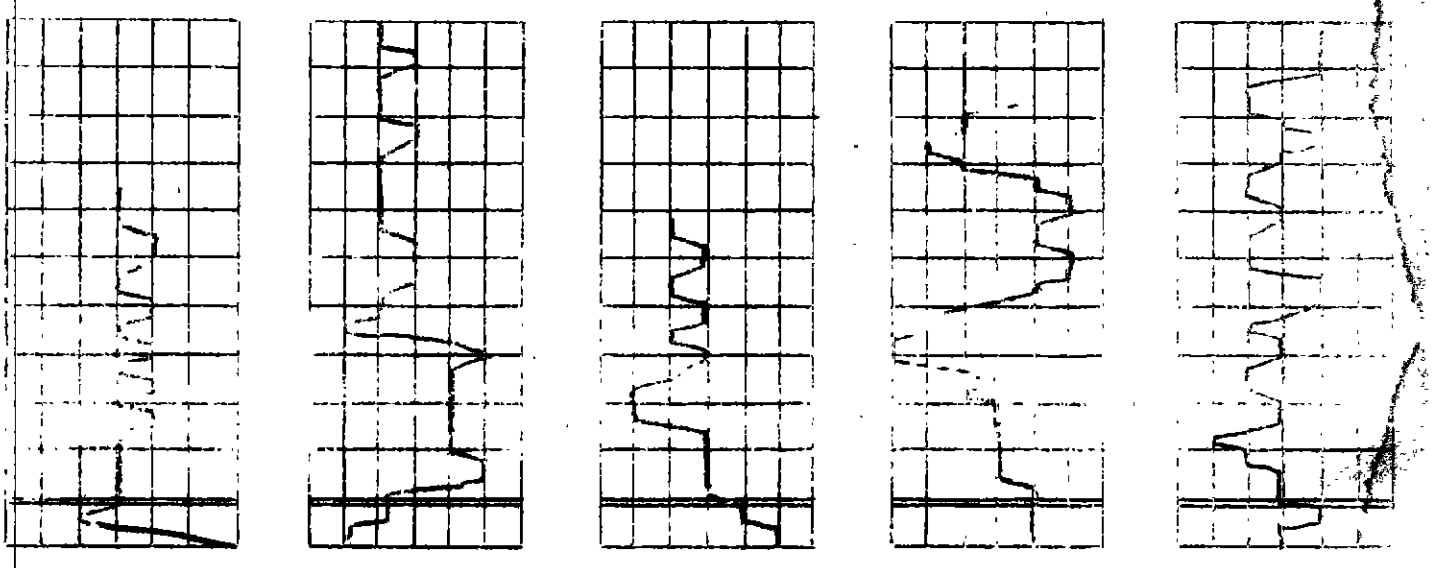
However, in spite of the lack of consistency among pilots, a certain amount of consistency for each individual pilot is revealed by the graphs. The upper row of Figure 7 shows graphs of 5 landings made by J. Stair, Sr., a pilot with 4500 hours of flying time. The five graphs are typical of the visual pattern whic



J. Stair, Jr. 450 hours



J. Stair, Jr. 500 hours



J. Kitto 1400 hours

characterized nearly all of the landings photographed for this pilot. Until within approximately 5 seconds of the actual landing, visual excursions between left and right are made. During the last five seconds of flight, the fixation is fixed fairly rigidly in area R3, the area immediately to the right of Front. J. Stair, Jr., however, who also showed a pattern of excursions between right and left until the last five seconds, tends to fixate in area L_2, the second area to the left of center, for the last five seconds of flight. J. Kitto, for whom 5 landings are shown in the bottom row of Figure 7, tends to continue the pattern of excursions between right and left up to the instant of the actual landing. It should be emphasized that all three pilots whose landings are graphed in Figure 7 are seasoned flyers.

The pilots whose landings are graphed in Figure 8 were both in the pre-solo stage of instruction. Wastl shows a lack of one feature that characterized nearly all of the records of experienced pilots, namely, fairly wide visual excursions at least up to the last four or five seconds before the landing. Bestor, however, shows visual patterns that are probably not distinguishable from those of such an experienced pilot as J. Kitto.

Another tendency revealed by the graphs is the tendency of many pilots to spend a certain portion of the last five seconds of flying time in looking directly toward the front of the ship. During this interval of time, the plane is at no time in such an attitude that a direct view of the ground can be obtained by looking through even the sides of the windshield. Since forward glances are found in experienced and inexperienced pilots alike, it is probable that during the time the eyes are directed ahead the pilot is actually picking up cues from the peripheral field of vision.

General Conclusions. Although no clear-cut and invariable differences were found in the eye-movement patterns of experienced and inexperienced pilots, several tendencies were sufficiently marked to justify certain tentative generalizations:

1. The experienced pilots almost invariably showed an excursion back and forth until the last five seconds before the landing. Inexperienced pilots did not all show these excursions.

2. During the last five seconds of flight, some of the experienced pilots continued these excursive movements, while others usually settled down on an area either to the right or left, but not alternately between right and left.

3. The "settling" referred to in (2) occurred with different pilots in any one of four areas: R_3, R_2, L_3, or L_2. While different pilots tended to utilize a different area for this settling process, there seemed to be no evidence that one area is "better" than another.

4. It was noted that several of the experienced pilots fixed their glances at an angle which was held for several seconds at a time. Others seemed to fix successively on spots some distance in front of the plane and then follow these spots for shorter or longer periods of time. Then the eyes jumped ahead to a new spot which was "followed through." The excursion of the eyes suggestive of this type of glance sometimes caused the eyes to rotate backward from one visual area into the next adjacent area, though at times the excursion was confined within a single visual area.

5. Throughout the experiment many comments of the pilots used as subjects were noted. Most of the pilots stated that they were not sure where they looked. It was rather interesting to observe that the few experienced pilots who insisted that there was a proper place to look in landing were likely to deviate from this suggested pattern in their own landings.

While the investigation indicates in general that there is no single patter of eye fixations that characterizes all experienced pilots, the comments enumerated above may give certain clues that will be helpful to instructors. Comments (1) and (5), for example, suggest the inadvisability of instructors insisting that students look at a certain specified place, and nowhere else, while an airplane is being landed.

The graphic records of all landings analyzed in this study are attached to this report.* Study of these records may reveal other tendencies that will have practical value to the flying instructor.**

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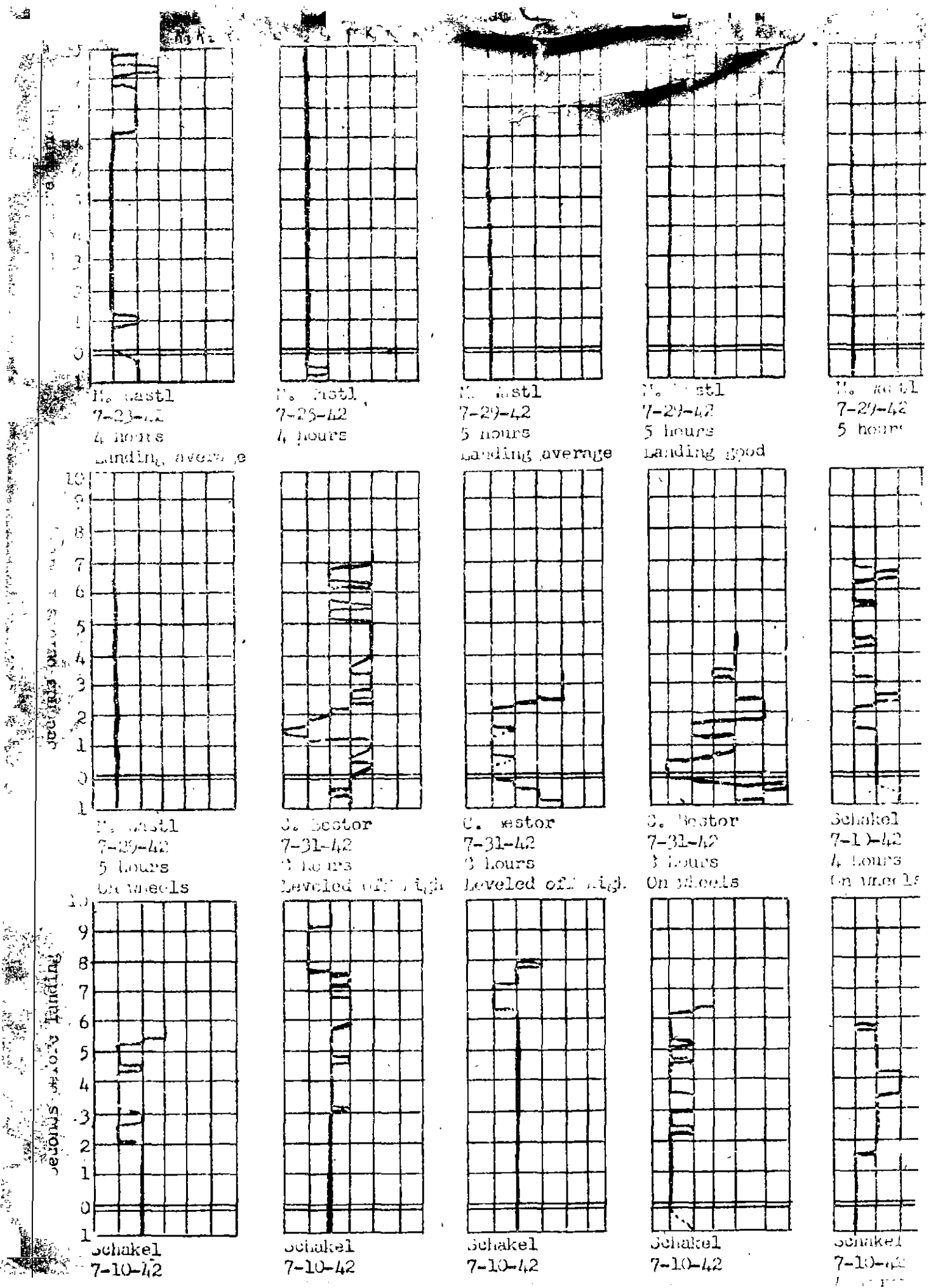
*Editor's note. In analyzing these records it is well to bear in mind that approximately 35% of the graphs are of landings made by the authors themselves.

**Editor's note. In connection with studies of peripheral vision it is interesting to note in these records that none of the men kept their eyes consistently fixed and their attention oriented only in the forward area during landing, i.e., none depended exclusively upon peripheral cues from the other areas during the last five seconds.

The following graphs are continuous records for each landing photographed in this investigation. They have been classified according to the experience of the pilots. Group I (which follows immediately) includes pilots who had not soloed at the time the records were taken. Group II includes pilots who had soloed but not obtained their private licenses. Group III includes private licensed pilots with less than 200 hours of flying time. Group IV includes pilots with over 200 hours of flying time.

For an interpretation of the following charts, see the preceding report, page 3.


Jerome's Smooth Landing
No. Castl
7-23-42
4 hours
Landing average
No. Castl
7-28-42
4 hours
No. Castl
7-29-42
5 hours
Landing average
No. Castl
7-29-42
5 hours
Landing good
No. Castl
7-29-42
5 hours
No. Castl
7-29-42
5 hours
On wheels
J. Bestor
7-31-42
3 hours
Leveled off high
C. Bestor
7-31-42
3 hours
Leveled off high.
J. Bestor
7-31-42
3 hours
On wheels
Schakel
7-10-42
4 hours
On wheels
Schakel
7-10-42
Schakel
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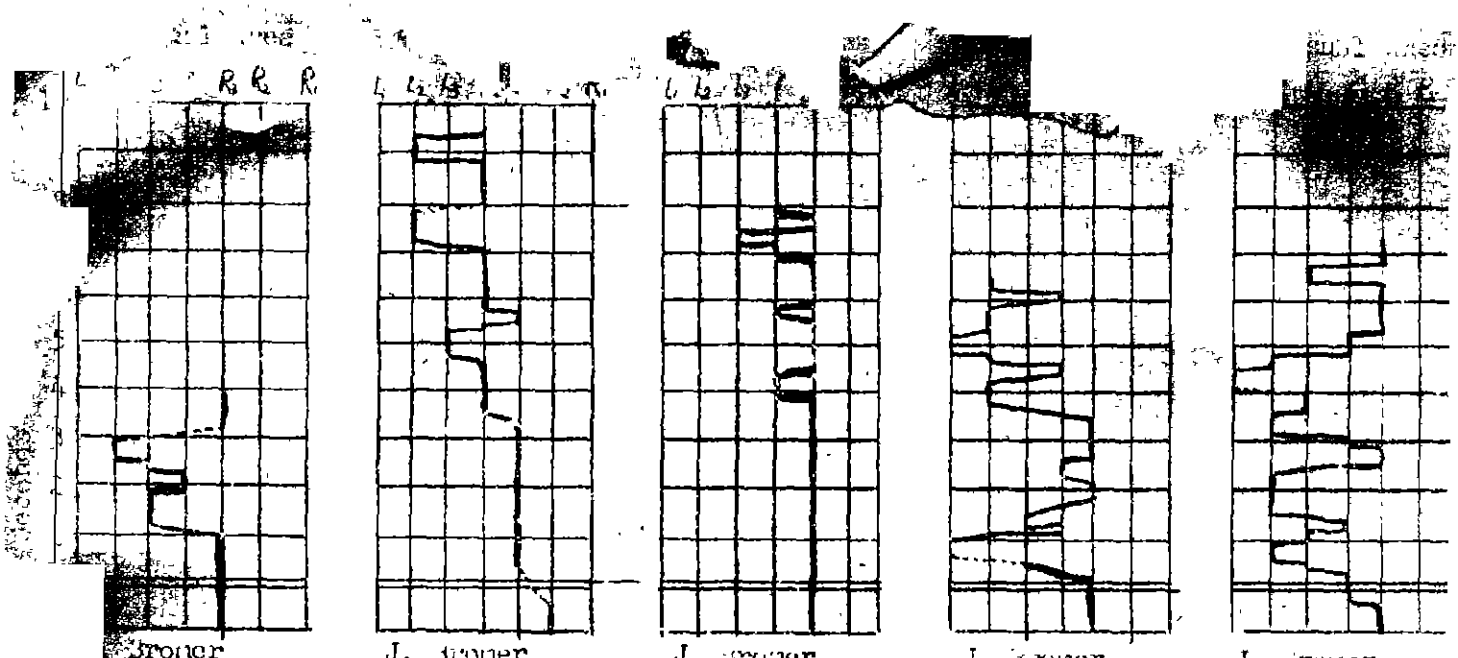
Schakel
7-10-42
Schakel
7-10-42



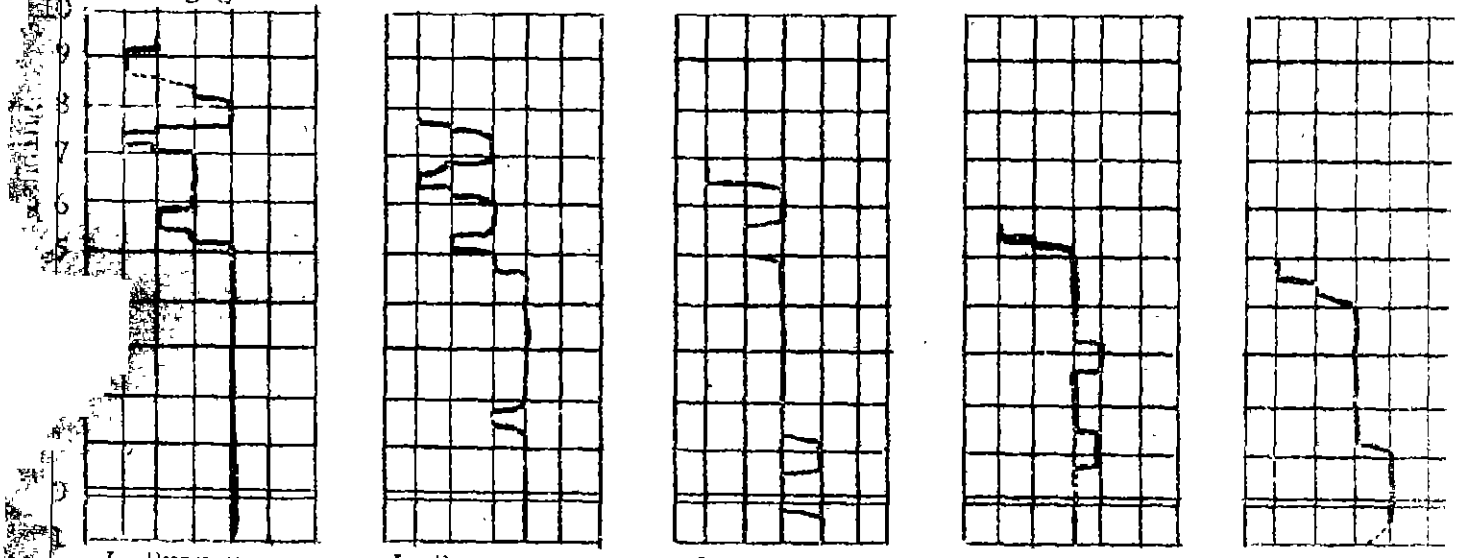
J. Broner
7-1-42
12 hours
Landing good

J. Broner
7-1-42
12 hours

J. Broner
7-6-42
13 hours

J. Broner
7-6-42
13 hours

J. Broner
7-6-42
13 hours



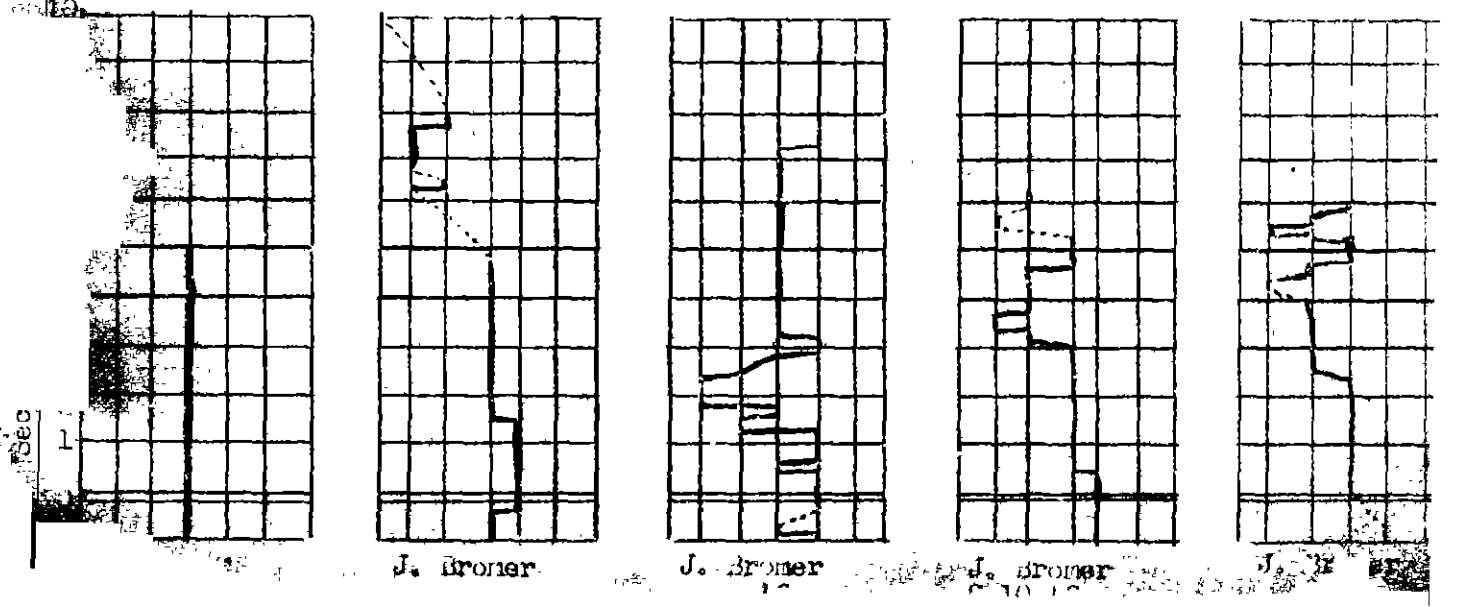
J. Broner
7-6-42
13 hours

J. Broner
7-6-42
13 hours

J. Broner
7-6-42
13 hours

J. Broner
7-7-42
13 hours

J. Broner
7-7-42
13 hours

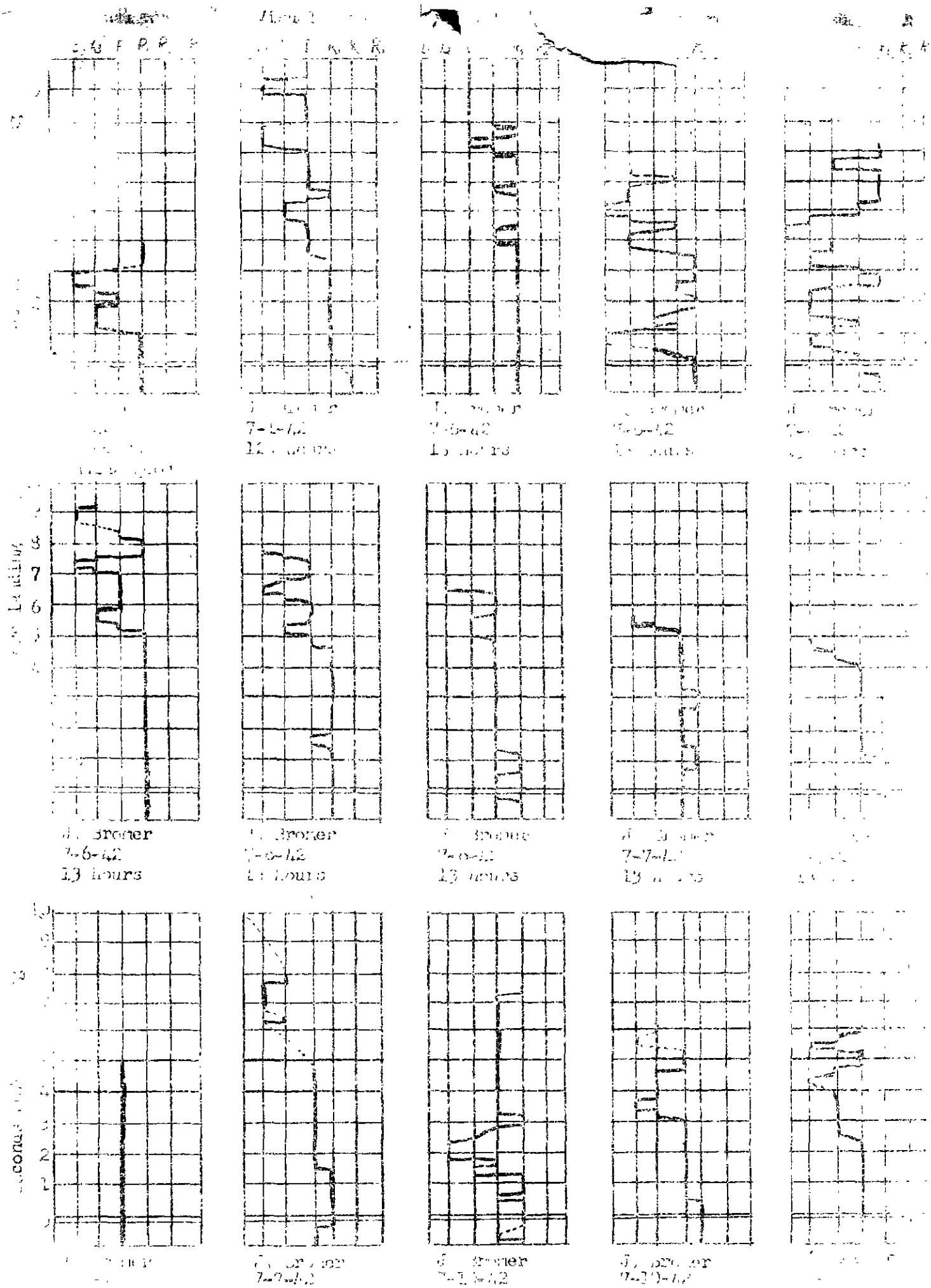


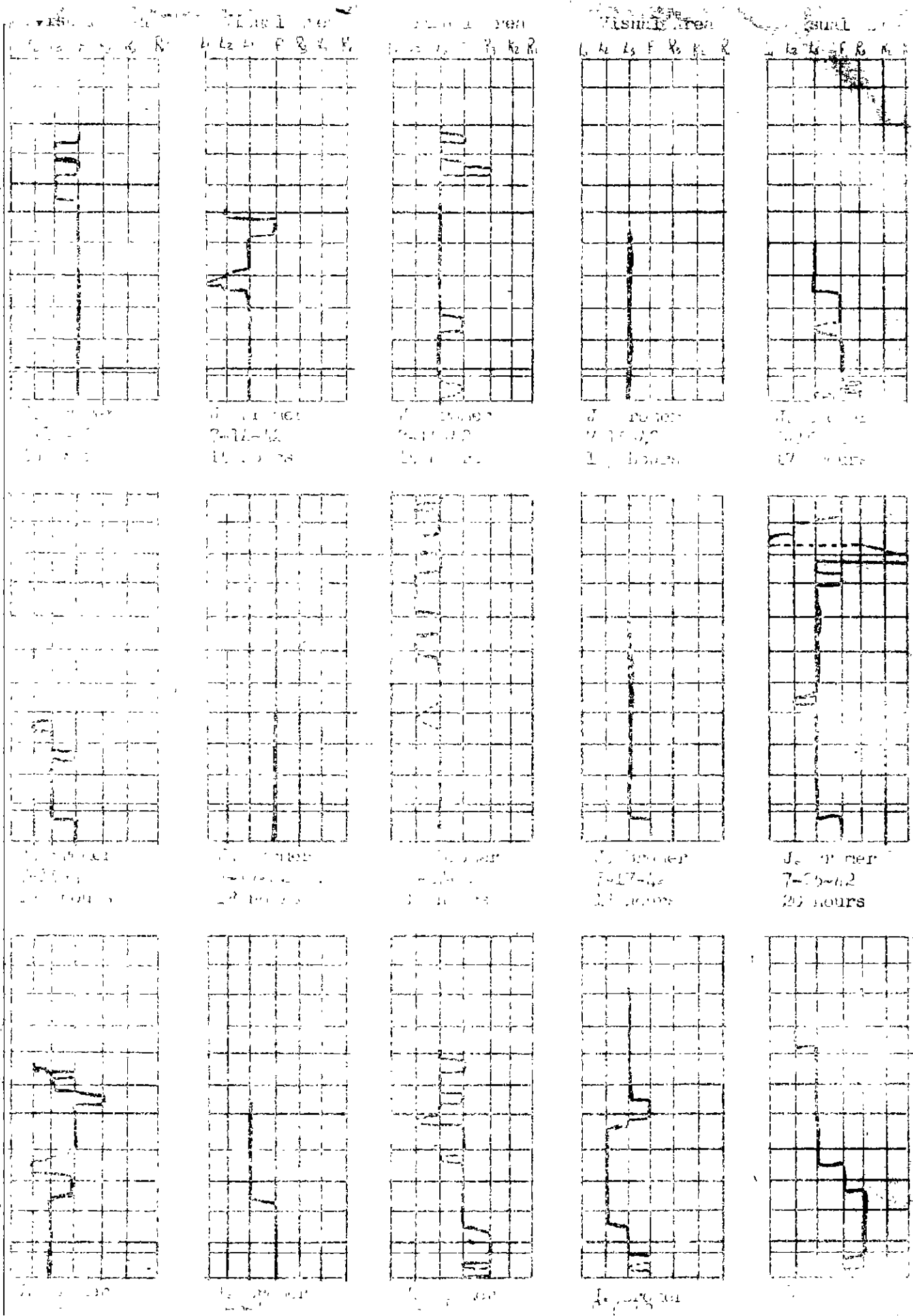
J. Broner

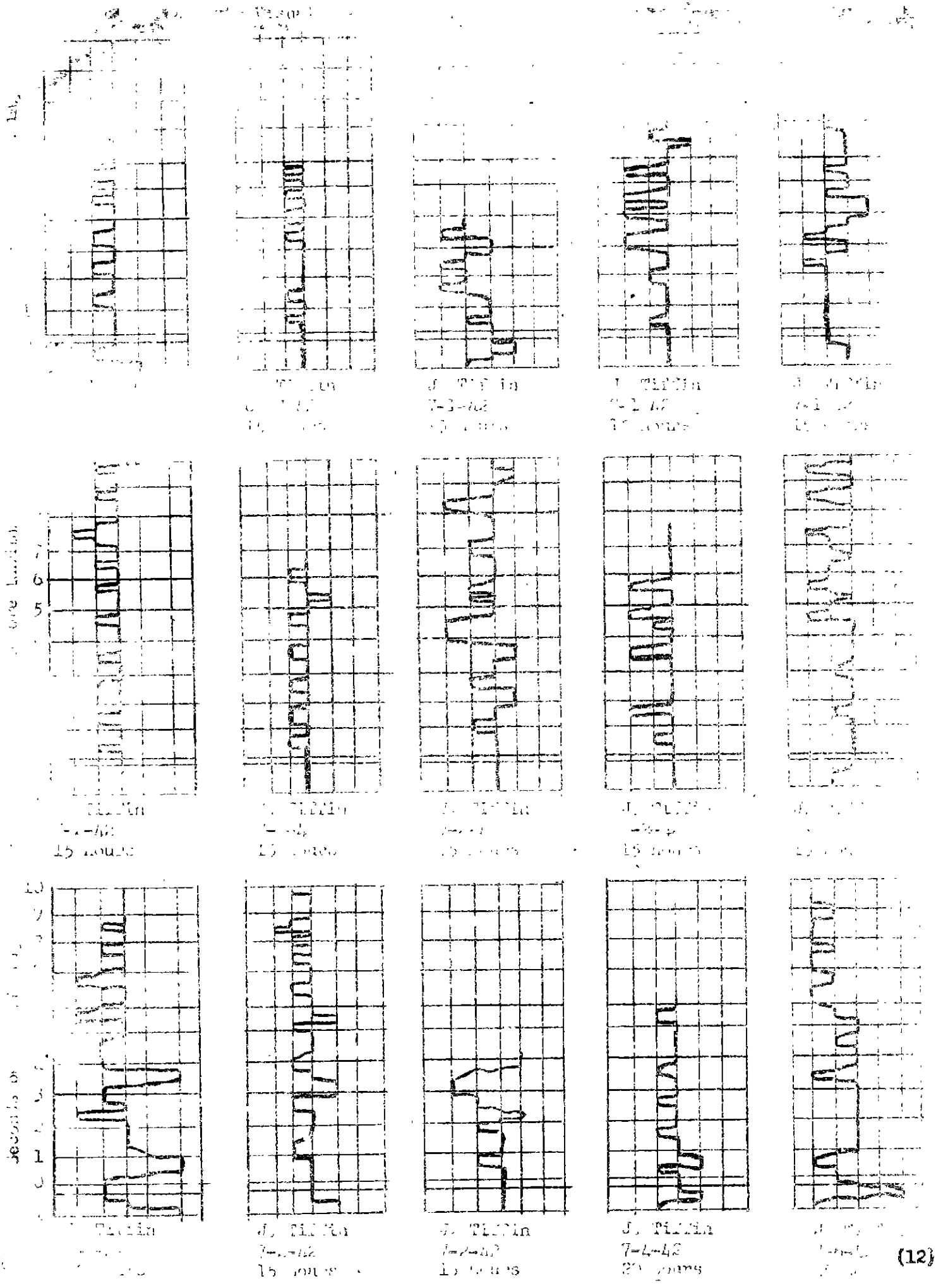
J. Broner

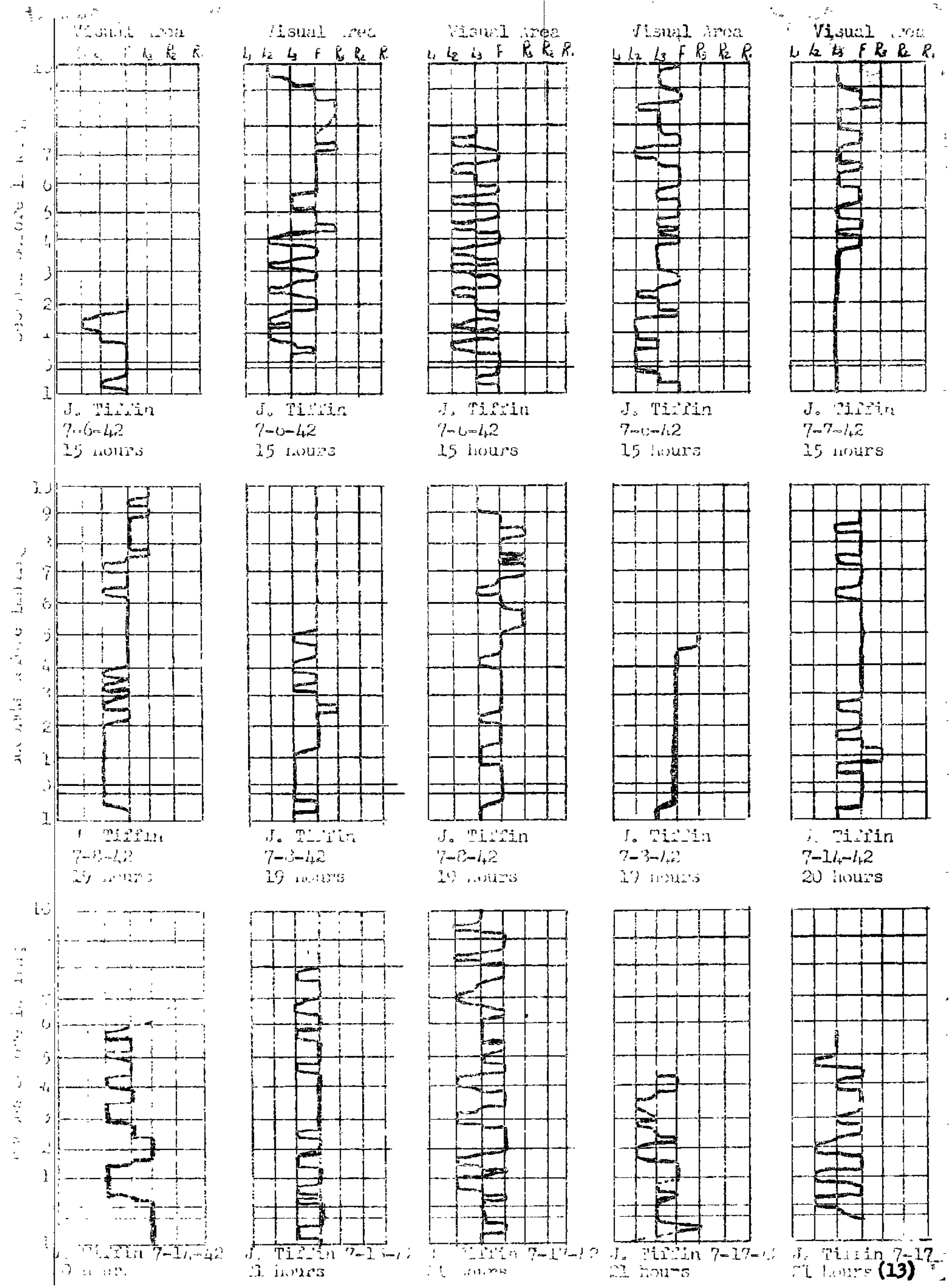
J. Broner

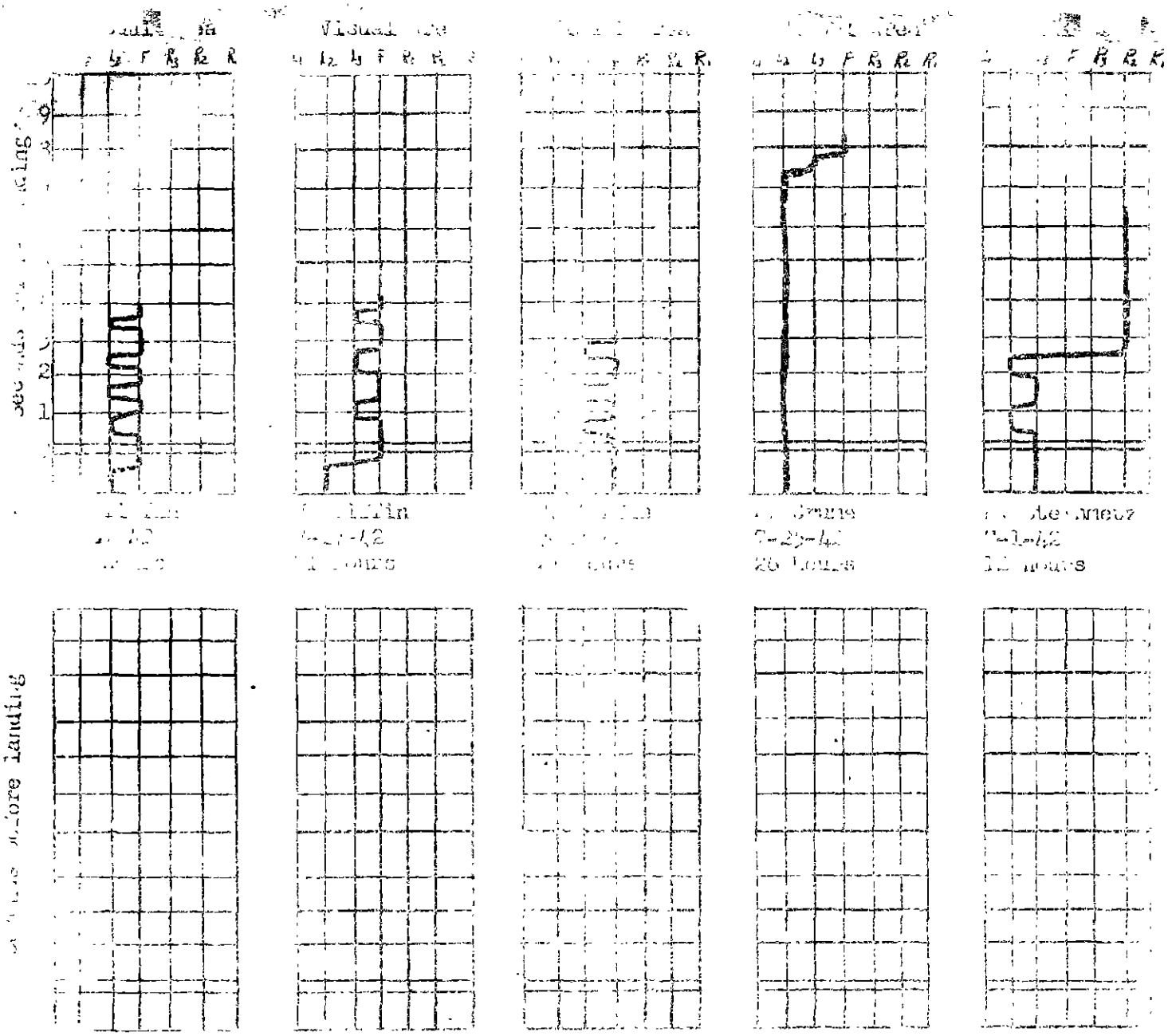
J. Broner



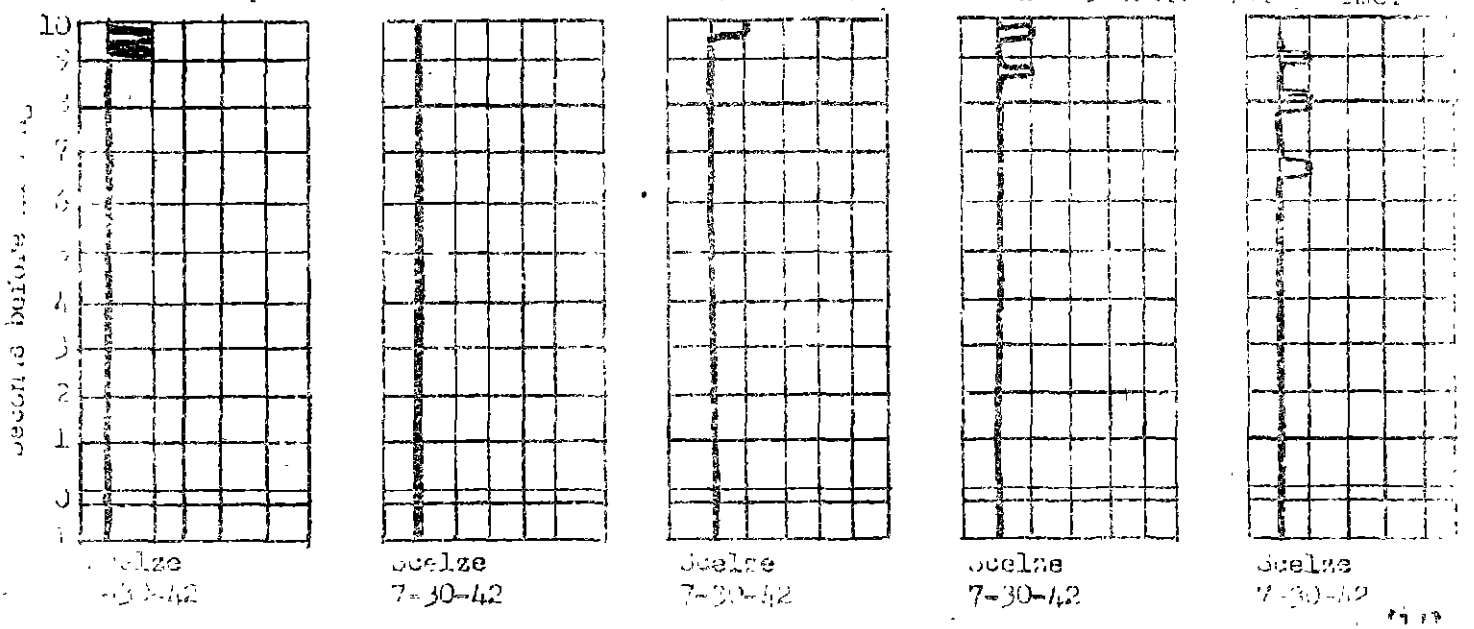


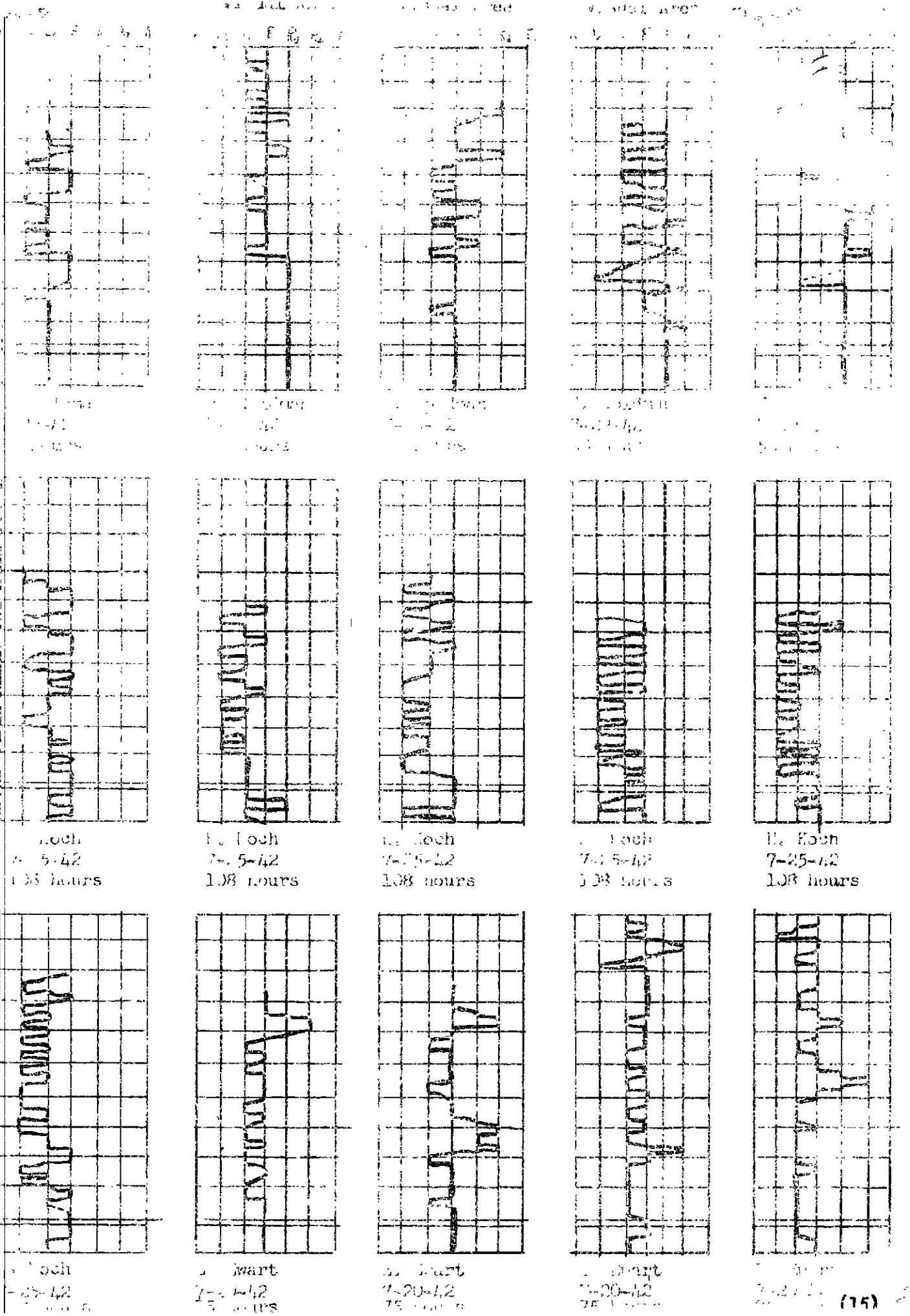



Visual Area
L1 L2 L3 F R3 R2 R1
J. Tiffin
7-6-42
15 hours
J. Tiffin
7-7-42
15 hours
J. Tiffin
7-8-42
19 hours
J. Tiffin
7-14-42
20 hours
J. Tiffin 7-17-42
21 hours
10
9
8
7
6
5
4
3
2
1



Group III. Pilots with private licenses and less than 200 hours flying time.





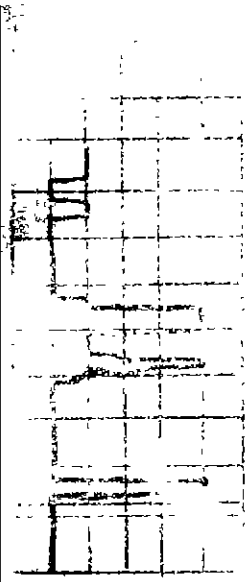
Koch
7-5-42
138 hours

Koch
7-5-42
138 hours

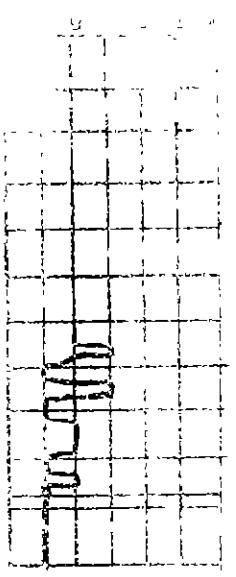
Koch
7-25-42
138 hours

Koch
7-25-42
138 hours

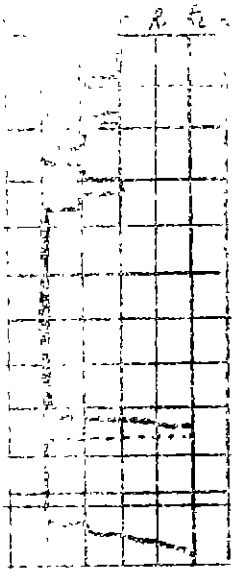
Wart
7-20-42

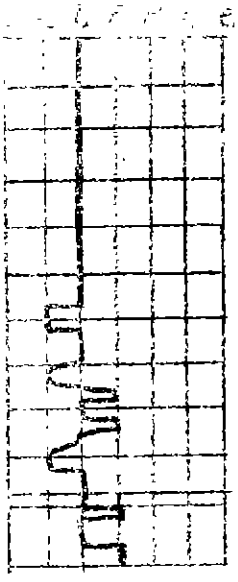


P. Schreiber
7-31-42
65 hours

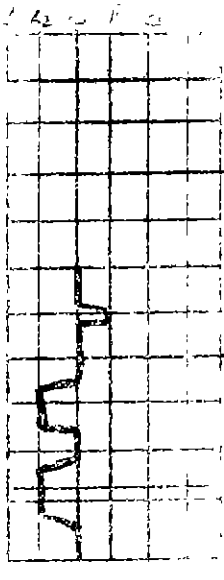


7-31-42

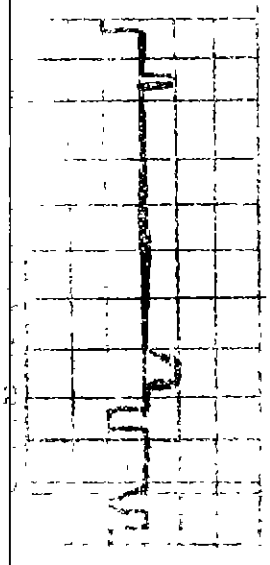


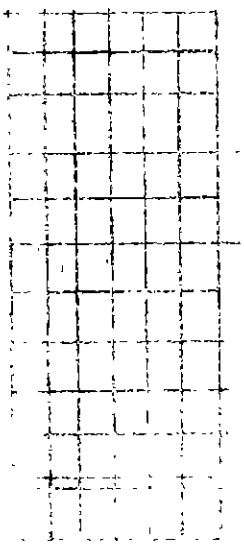


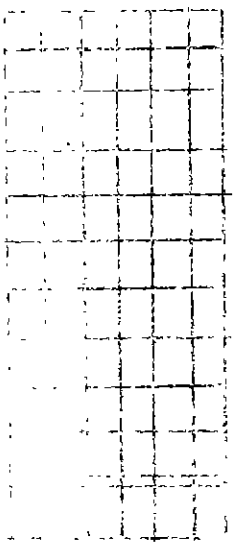
7-13-42

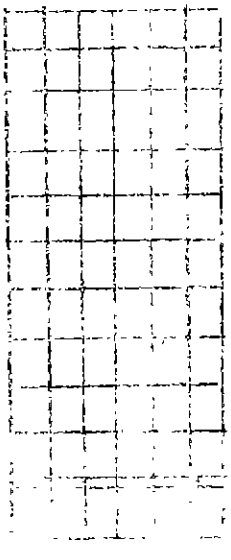


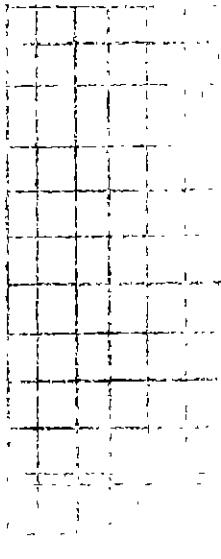
7-31-42
59 hours

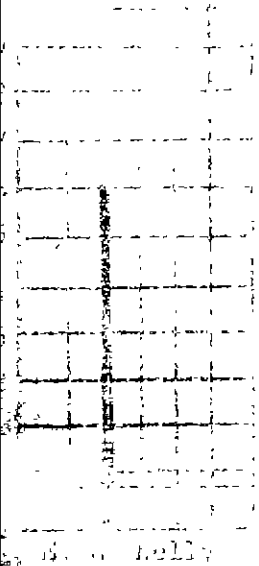


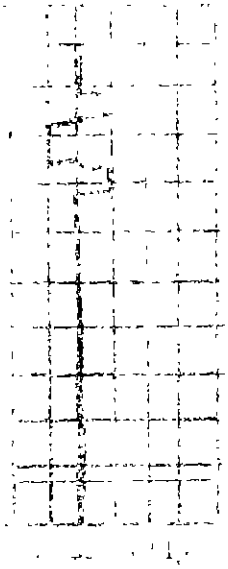


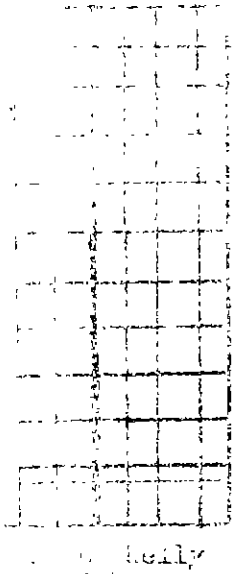


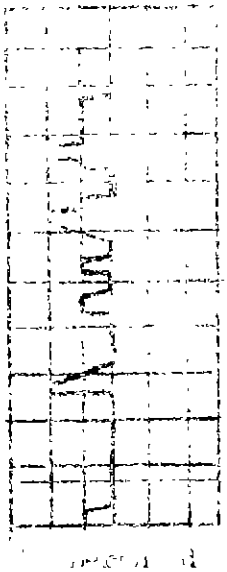


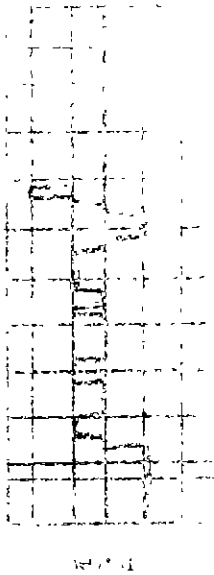




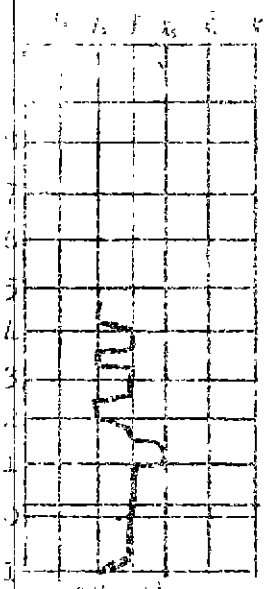




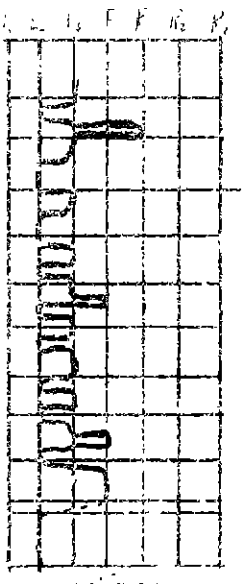




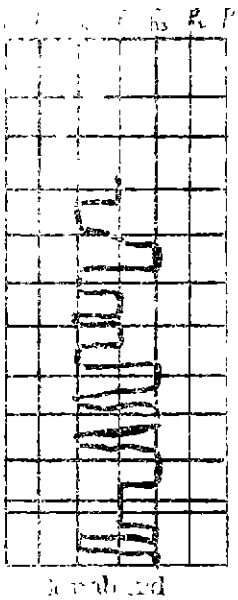
7-27-42



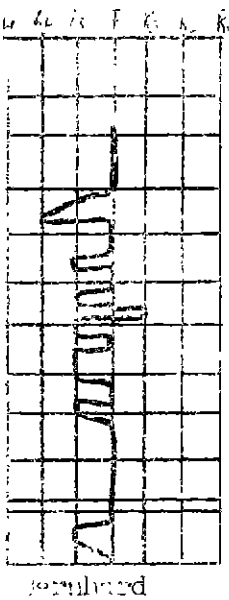
Normal
7-13-42
265 hours



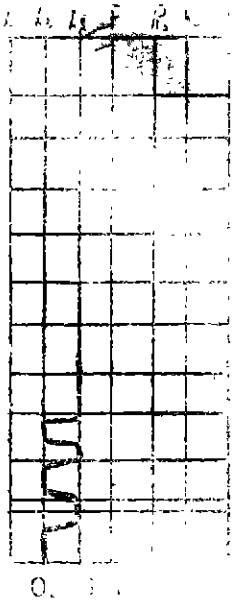
Semifinal
7-13-42
265 hours



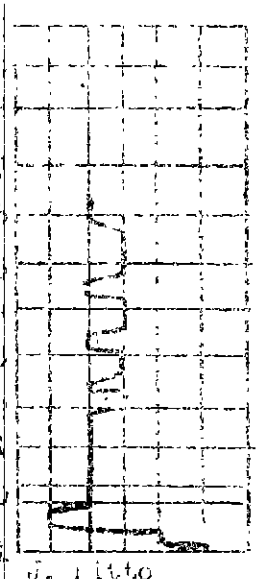
Semifinal
7-13-42
265 hours



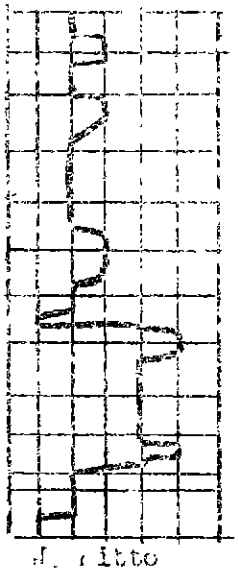
Semifinal
7-13-42
265 hours



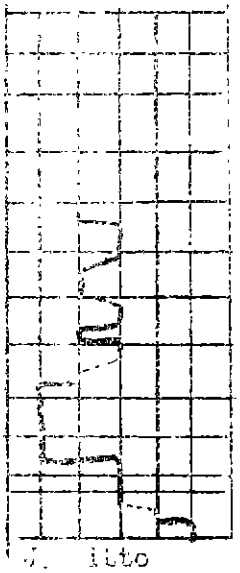
Original
7-23-42
370 hours



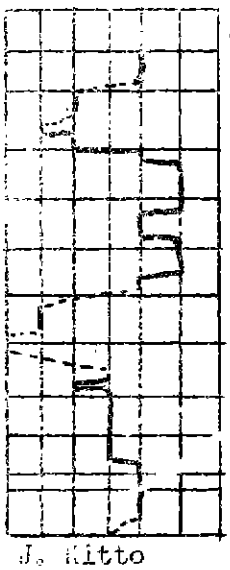
J. Kitto
7-7-42
1400 hours



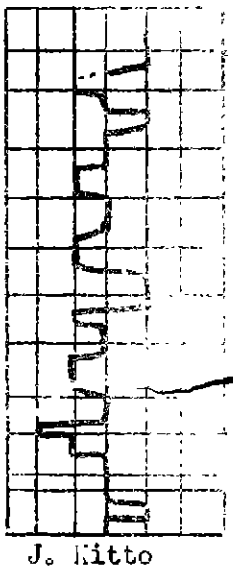
J. Kitto
7-7-42
1400 hours



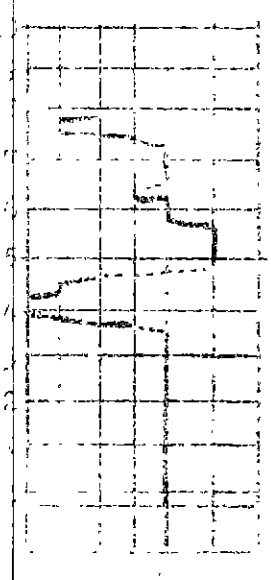
J. Kitto
7-7-42
1400 hours

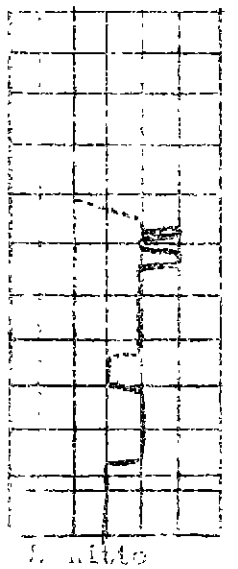


J. Kitto
7-7-42
1400 hours

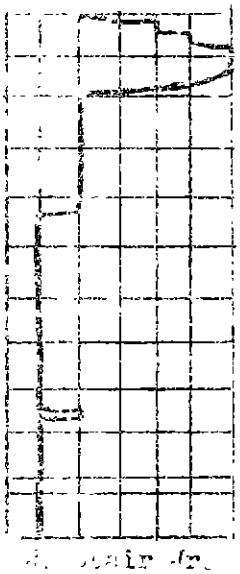


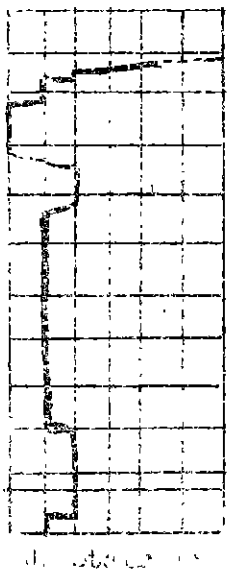
J. Kitto
7-7-42
1400 hours

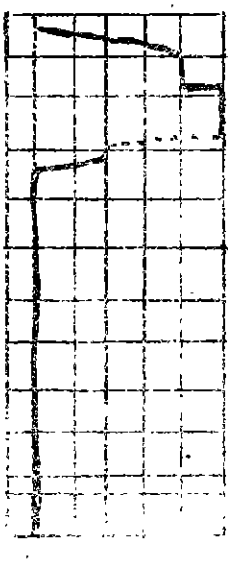


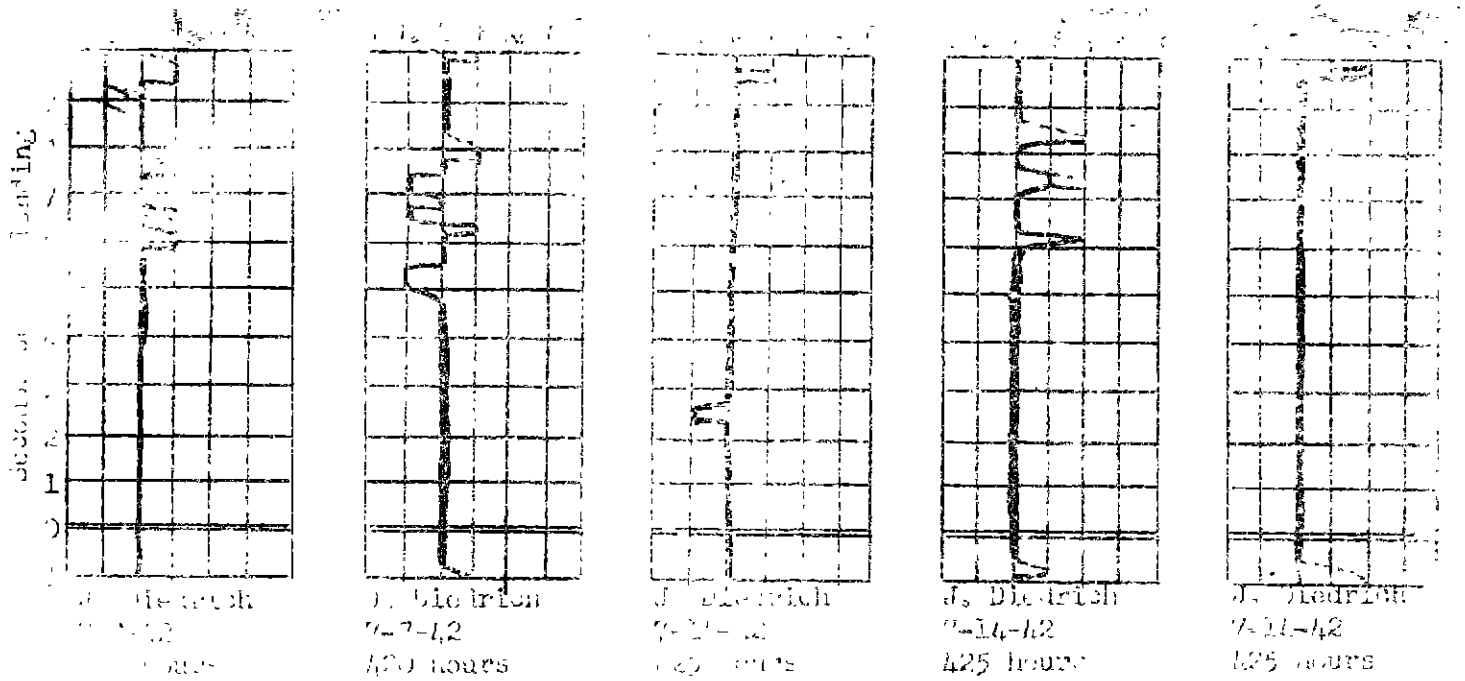


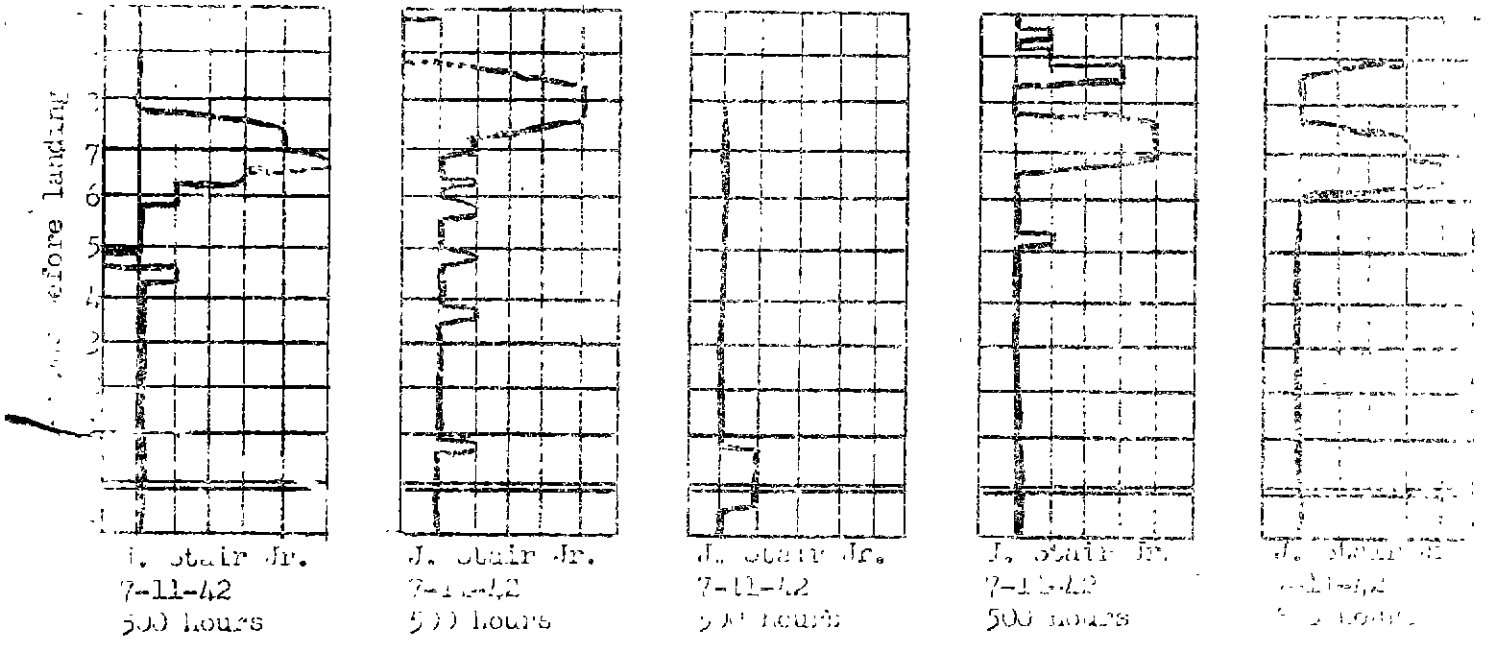
J. Kitto
7-7-42

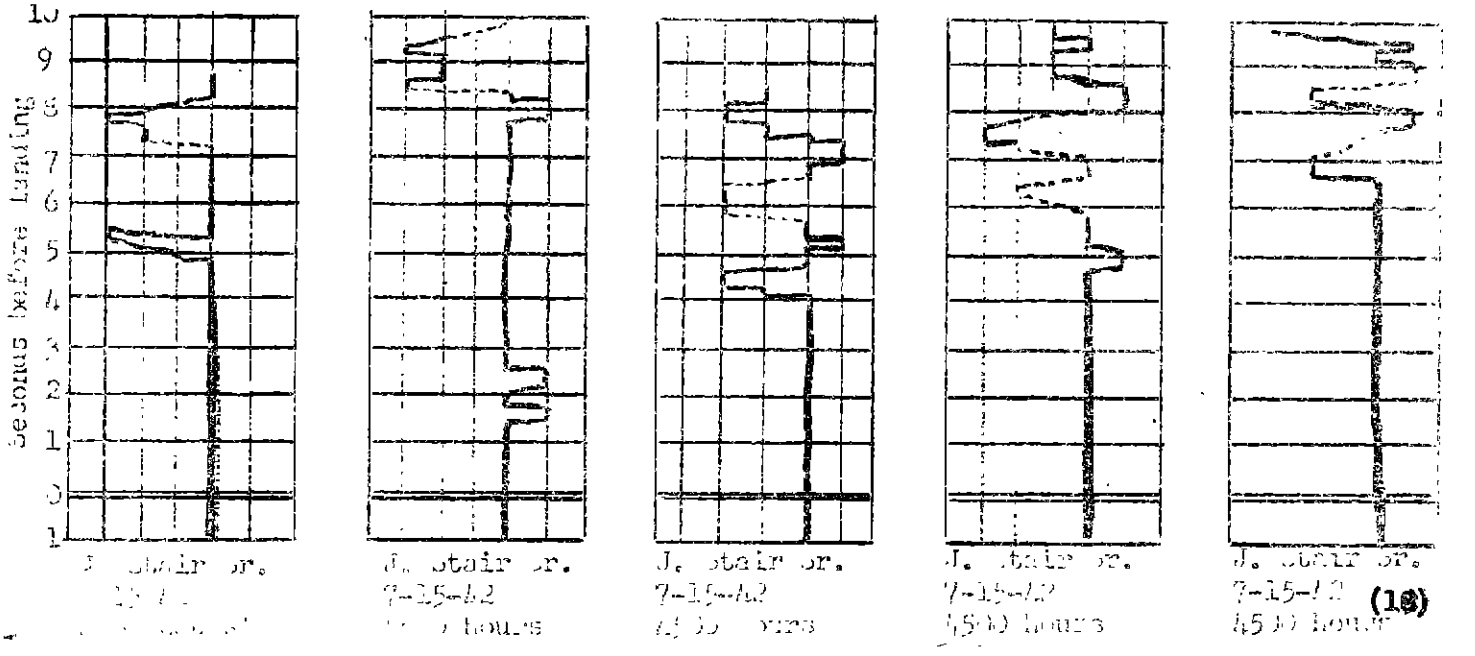


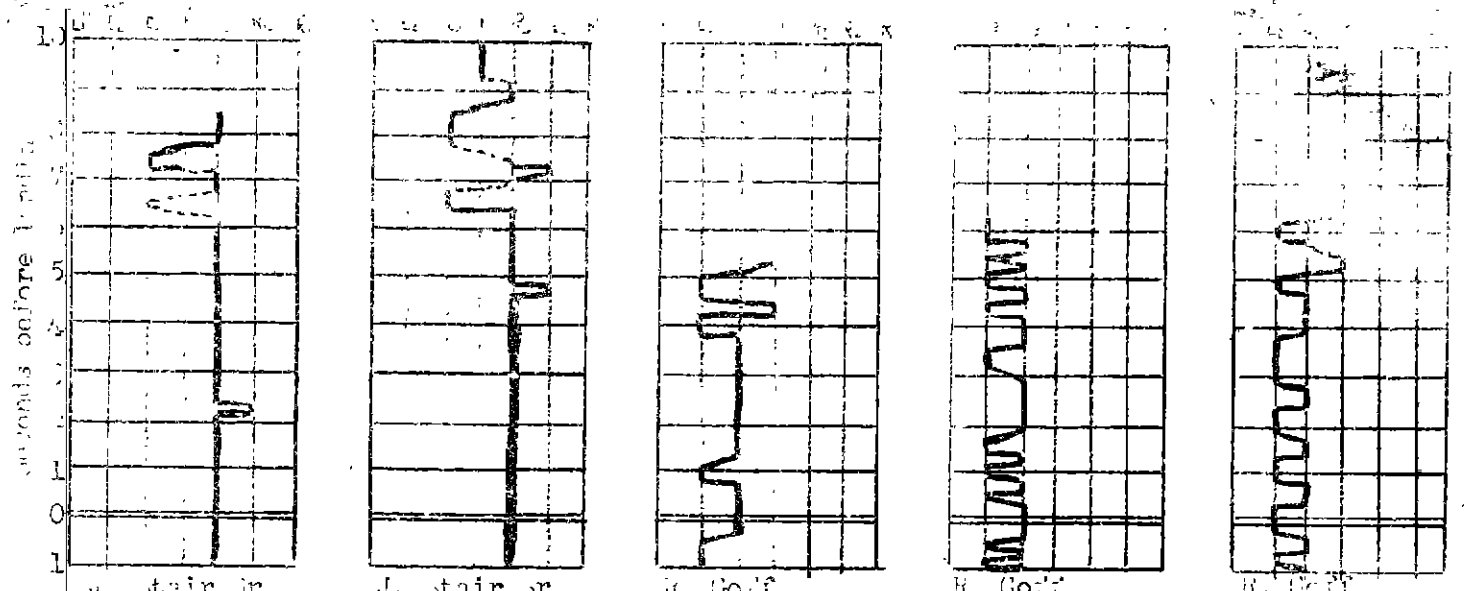





Seconds before landing
J. Dietrich
7-7-42
420 hours
J. Dietrich
7-14-42
425 hours
J. Dietrich
7-11-42
425 hours


Seconds before landing
J. Stair Jr.
7-11-42
500 hours
J. Stair Jr.
7-15-42
500 hours


Seconds before landing
J. Stair Jr.
7-15-42
500 hours
J. Stair Jr.
7-15-42
4500 hours



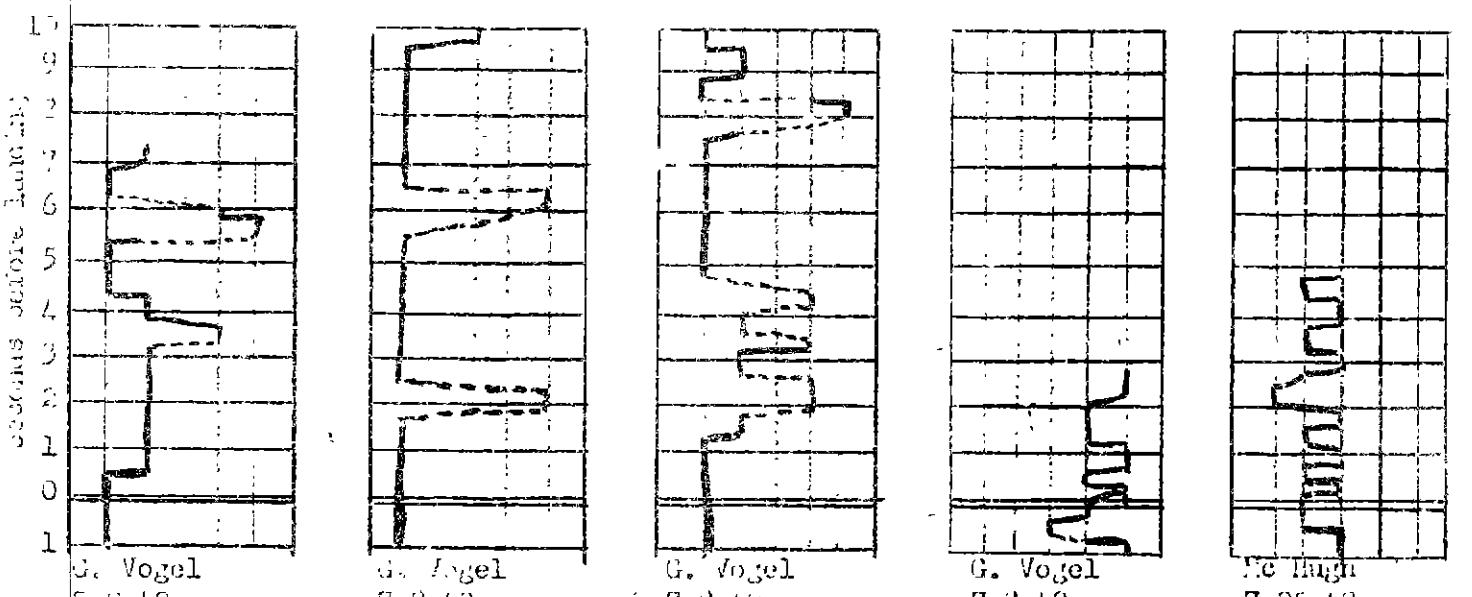
J. Stair Jr.
7-15-42
4500 hours

J. Stair Jr.
7-15-42
4500 hours

R. Goff
6-27-42
870 hours

R. Goff
6-27-42
870 hours

R. Goff
6-27-42
870 hours



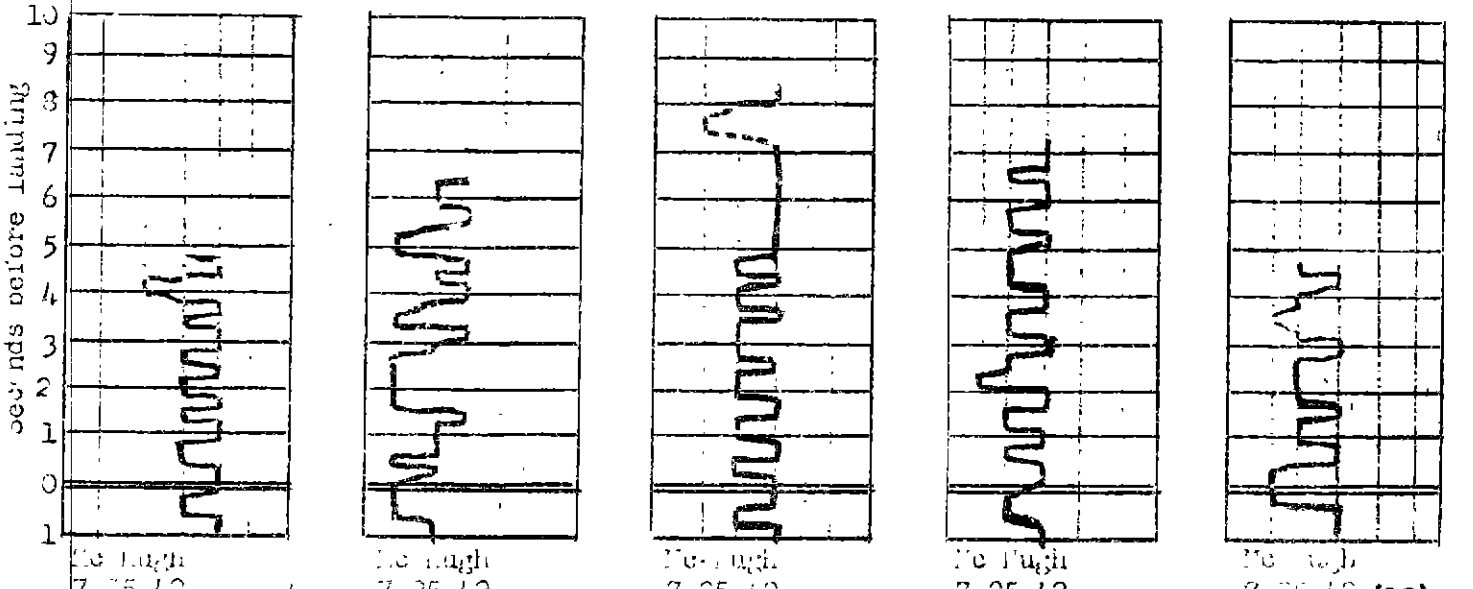
G. Vogel
7-3-42
430 hours

G. Vogel
7-3-42
430 hours

G. Vogel
7-3-42
430 hours

G. Vogel
7-3-42
430 hours

Mc Hugh
7-25-42
330 hours



Mc Hugh
7-25-42
330 hours

Mc Hugh
7-25-42
330 hours

Mc Hugh
7-25-42
330 hours

Mc Hugh
7-25-42
330 hours

Mc Hugh
7-25-42
330 hours

(20)

SUPPLEMENT

The following pages present two pertinent reports of progress on a study of visual depth perception in aviation, conducted by Dr Carl Pfaffmann, Brown University.

FIRST REPORT OF PROGRESS ON THE STUDY OF VISUAL DEPTH PERCEPTION IN AVIATION

by

Carl Pfaffmann

January 1941

So far I have interviewed and questioned 15 CAA students on the visual clues used in landing. It was necessary to conduct most of the interviews at the Psychological Laboratory to avoid the distraction and noise of the airport. In general, most individuals stated that they usually look at the ground at either side of the plane just as they are levelling off. They look directly at the ground about 30 ft. away in the case of those who look ahead. Some look directly out to the side through the wing struts and a few maintain that they look over the wheels to the ground below. The students in the first two categories usually state that they know immediately what their distance above the ground is at any one instant. The last group say they use the distance between the ground and the wheel as a kind of "measuring stick." I'm rather skeptical of this last point particularily since I myself find it difficult to watch the wheels under ordinary circumstances of flight. In any case, I am checking such points at additional interviews both at the lab. and at the airport. All students interviewed have been instructed to observe their own behavior.

I am keeping a complete introspective account of my own flying experience. To date this consists of 5 hours dual instruction. On the basis of this I have analyzed the estimation of distance and height into several stages. At altitudes above 100 ft., estimations of both height and distance are quite inaccurate. The ground resembles a model landscape in which the houses and trees appear only as miniatures. As the plane glides toward the ground a "threshold altitude" is reached at about 75 to 100 ft. where the houses and trees suddenly become "real." Here I obtain the first clear and correct notion of height above the ground and distance from the landing field. At this point I usually realize that I am going to undershoot or overshoot the edge of the landing field. I believe that at this stage "size constancy" and perhaps binocular stereopsis begin to function. During the first few landings, this stage of fairly accurate depth perception was followed by another stage of inaccuracy which began at about 10 ft. and lasted until the plane touched or hit the ground. At this time my gaze remained fixed over the nose of the plane. As the plane leveled off, my field of foveal vision included only the cowling of the engine and the horizon. The ground on either side was observed with peripheral vision and consequently appeared to move past with a high apparent velocity. Estimation of height was poor and consequently landings were bad.

During one such landing I happened to glance away from the cowling to the ground on one side of the plane. In that glance, the apparent movement of the ground was stopped and I clearly saw the surface of the ground with foveal vision. At that instant I had an immediate almost "insightful" awareness of the distance separating me from the ground. With this change in fixation, the third stage became clear and accurate. Since then I have had little difficulty

in estimating height above [illegible] in making safe landings. I judge that [illegible] at the ground further than 30 ft.

I feel that I can't emphasize too much the importance of these momentary fixations along the ground during the last part of the landing maneuver. My own experience was so clear and immediate during that first glance to one side and so important for my orientation that I believe this is the most crucial part of the problem of depth perception in flying. Furthermore, since I tend to look at the ground some distance away, the apparent movement of the ground with respect to myself is not very great. I don't think the dynamic features of this situation are so important.

I have recently begun to interview the flying instructors at Providence. One "old-timer" gave me a really good psychological description which agreed with all that I have just described. Fortunately for the validity of my own analysis, I obtained his report after mine was complete in its essentials. Several other instructors were more vague when questioned about this problem. I have since given them instructions so that they may observe their own performance more critically. I have the impression that the better instructors may have made such an analysis on their own and they are therefore able to tell their students what to look for.

If the above analysis of visual function is correct I should expect photographs of head and eye movements taken during landings to show a series of eye fixations with the angle of gaze directed slightly to one side and downward. I shall be very interested to compare notes with Prof. O'Brien on this point. When I have more data, I am planning to visit Rochester.

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SECOND PROGRESS REPORT

Carl Pfaffmann, Brown University

April 1941

As part of the introspective study of visual cues in landing, the writer sent letters of inquiry to a number of psychologists who have received flight training under the C.A.A. To date seven satisfactory answers have been received. A summary of these is presented below.

A. The estimation of altitude when circling the field, etc.

Nearly everyone reported that estimations of altitude were based on the size of objects on the ground, the clearness of detail in these objects and the apparent velocity of the ground below the plane. These cues, however, were not learned in terms of the altimeter directly, but only indirectly in terms of the various maneuvers that were carried out at certain specified altitudes, as indicated by the altimeter. After a time one comes to know the appearance of the ground for the different maneuvers. Thus 500 - 600 ft. for one man is the altitude at which he performs "pylon eights." He knows what the ground looks like for this maneuver. In nearly every case it was emphasized that one behaved to altitude and did not merely estimate it. Another man judged altitude in terms of how long it would take to glide to a landing.

The cues of size and detail of objects on the ground are learned for specific items and landmarks. Very often a special landmark like a white house, for example, serves as a sign post over which the student begins a 90° turn at 300-400 ft. for the approach. When the student has to land on a completely strange field or even on another runway of the same field he may make errors in landing. One man (ACW) pointed out that the more familiar the landmarks, the more accurate was his estimation of altitude. When landing at a strange airport he usually underestimated altitude and came in too high. Apparently the ability to generalize landing habits develops gradually. One must learn to do without the specific cues which are first used and to respond to whatever is common to all landing situations.

B. Approaching the field.

In making the approach, the same cues for altitude are used. Clearness of detail becomes more important. This apparently means that the ground or objects on the ground acquire surface microstructure. Objects on the field boundary, landing lights, etc., are clearly seen. The apparent velocity of the ground is seen to increase.

An additional factor or judgment is stressed by three observers. (ACW, WEV, JF) This is the judgment of the vertical angle between the pilot and the runway. If the runway is too "high" or "flat" the plane is too low for a satisfactory landing.

In estimating where the plane will land it must be remembered that the angle of glide is fixed within certain limits. Therefore the altitude and

distance from the field at which the glide is begun determines where the plane will land unless certain adjustments like "slipping" or "gunning the throttle" are made. As noted previously, many people rely on definite landmarks in beginning the approach. After the glide is begun, most of the group report that they merely look at the spot where they expect to land. One man (ACW) tends to overlook the forward travel of the plane and usually lands beyond the spot chosen. He also stated that if certain obstructions at the edge of the field are cleared comfortably the plane will land in a specified area of the field.

Another individual (EE) sights along the nose of the tandem cub. He feels relatively certain that the plane will land at a spot just beyond the point sighted. The lack of transfer of this cue to another type plane is also reported. In addition, when making an approach, he notes the relation of certain objects on the field boundary to the nose of the plane, or a spot on the windshield. He then follows this relation as the plane glides in to tell whether these objects will be cleared safely.

C. Landing.

In determining the point at which to level off there is uniform agreement among all observers that they look directly at the ground fairly close to the plane. Estimates in individual cases place these fixation distances from 10-75 ft. in front of the plane and slightly to the side. One man (EE) originally had difficulty with a tendency to lean to one side in order to look out. He now sits upright and scans the area on both sides plus occasional rapid glances at right angles to the plane. In the early stages of learning he used to say that when the blades of grass could be seen clearly it was time to pull back on the stick. Since becoming more proficient this cue is used less. Now, he states, it would be more accurate to say that he "feels" the plane in. In another case, the observer (ACW) reported that after the plane is leveled off he looks to the ground at the left and about 15-25 ft. to the front. A blur that has a definite texture is seen as the ground goes by. He tries to keep this coming up towards himself at a smooth even rate.

Another observer, (JF) "feels" the wheels and tail skid as extensions of his own body so that he can "feel" their approach to the surface as he watches the ground come up. During this process he looks about 10 ft. in front of the plane. It is interesting that most individuals who restrict their gaze to one side at this stage usually look to the left. Another observer (AST) reports that he had difficulty in landing because he concentrated too much on the nose of the plane when it was leveling off. This left insufficient information as to height above the ground. To quote him, "I should be concentrating on the ground height and observing the attitude of the ship with indirect (peripheral) vision rather than vice versa."

These reports in this last section indicate that direct foveal vision is used in the last stages of landing particularly when the plane is being leveled off and "set down." This regard permits an estimation of height above the ground. This substantiates one of the conclusions presented in the first progress report on this study.