A REVISED SERIAL REACTION TIME APPARATUS FOR USE IN APPRAISING FLYING APTITUDE

by

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and

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A report on research conducted under grants-in-aid to the Division of Research, Graduate School of Business Administration, Harvard University by 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

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

August 28, 1944

Dr. Dean R. Brimhall, Director
Airman Development Division
Civil Aeronautics Administration
Washington, D. C.

Dear Dr. Brimhall:

Attached is a report entitled A Revised Serial Reaction Time Apparatus for Use in Appraising Flying Aptitude by Ross A. McFarland and Ralph C. Channell. This report 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 issued by the Airman Development Division, Civil Aeronautics Administration.

This paper contains a description of the original and revised forms of the Washburn Serial Action Apparatus along with test data obtained on groups of subjects differing in age, experience, and success in flight training. The report, which is one of a number to be devoted primarily to apparatus, is of particular interest because of the wide use which has been made of the test in the selection and classification of pilots.

Cordially yours,

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

MSV:ts

sc 9-15-44

EDITORIAL FOREWORD

One important by-product of the research program of the National Research Council Committee on Selection and Training of Aircraft Pilots has been the development of new apparatus and the improvement of existing apparatus in the field of flight aptitude testing and flight performance recording. This report on the use of the original form and the development of a revised form of a widely used psychomotor test represents an example of such a by-product. It describes a revision of the Mashburn Automatic Serial Action Apparatus growing out of a study involving the testing of aviation cadets at the Naval Air Station, Pensacola, Florida. Other reports, treating the Pensacola data in greater detail and describing other apparatus developments, will be published in the Technical Series in the near future.

Tests of this type have had a rather long history in pilot aviation selection research.[1] Unfortunately the history of this test is complicated by the fact that many versions of the test were developed by individual investigators and different names given to the resulting models. O'Rourke in 1926 constructed a Complex Coordinator. Mashburn called his version, developed with Constable, an Automatic Serial Action Apparatus. Reid in England constructed a Reaction Test. The form being used at present in the U. S. Army Air Force testing program is called the S.A.M. Complex Coordination Test. The revision of the Mashburn described in this report is called the Revised Serial Reaction Time Apparatus.

Until such time as one version becomes the established model and the name becomes standardized it must be remembered that they all provide much the same type of test situation, viz., selective responses by means of simulated airplane controls to a changing series of signal lights.

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[1] An historical introduction to aviation psychology. Washington, D.C.: Civil Aeronautics Administration Division of Research, Report No. 4.

CONTENTS

SUMMARY

Since the first World War investigators both here and abroad have been interested in the relationship between measures obtained on tests of psychomotor behavior and the complex coordination of hand and foot movements required in flying a plane. During and subsequent to that war experimentation with equipment like the Thorne Reaction Time Test and the O'Rourke Complex Coordinator, developed in America, and the Reid Reaction Test, developed in England, was conducted to determine the extent to which measures on these instruments were of predictive value in the selection of trainees. Findings seemed to indicate that good performance on motor tests of the serial reaction type had some relationship to success in flight training.

With the aid of the background of these earlier investigations, Col. N. O. Mashburn supervised the building of an instrument in which the actual control operations of a plane were simulated, and in which serial reaction of hands and feet was demanded in the testing procedure. Very early this instrument was found to be of value in differentiating between good and poor pilot trainees.

This report presents a description of a simplified revision of this equipment differing from the original in that it is constructed of parts purchased from standard manufacturers, making it inexpensive to build, fairly light in construction, and easy to replace spare parts. All equipment constructed from the specifications presented are comparable, facilitating standardization of procedure and operation. Other characteristics of the revised model are the inclusion of stimulus lights, relays, buzzer, and transformer in a compact metal unit, and the introduction of "distraction" lights on the panel assembly.

Preliminary data were collected with both the original and revised forms of the equipment on more than 1800 subjects, varying widely in flying experience and representing both civilian and naval pilots. An analysis was made of the obtained scores and tests of statistical significance applied to determine if the differences between groups of successful and unsuccessful pilots were significant. The following tentative conclusions and suggestions resulted from this study:

1. In each of the groups studied the differences in distribution between the scores of unsuccessful and successful pilots were significant when evaluated in terms of the critical ratios based on the standard errors of the differences between means, and the chi-square P values. The criteria for judging success were (1) time to solo and time for certification for pilot's license (civilian groups) and (2) pass-fail performance during flight training (naval groups). This preliminary evidence suggests that the test would be useful as one of a battery to appraise factors relating to the selection of pilots most likely to succeed in flight training. It must be pointed out, however, that all pilots ranking high on the test were not successful in flight training, indicating that other factors are involved in learning to fly which are not measured by this test.

2. Intercorrelations among the three series of 13 settings were sufficiently high to suggest that the test, as a whole, possesses sufficient reliability for further research on the use of the apparatus in the prediction of flight success.

3. Factors such as age, flight experience, and motivation influence performance on this test. The data suggest that the test is more applicable for use with beginning students, or those in the early stages of flight training, since these groups showed a greater spread of scores.

A REVISED SERIAL REACTION APPARATUS FOR USE IN APPRAISING FLYING APTITUDE

INTRODUCTION

Early in the history of pilot training it was discovered that many student pilots failed to complete their flight training in spite of the fact that they had passed rigid physical examinations at the time of original selection. This fact led to the development of selection techniques directed toward factors other than those related to physical fitness. Since it appeared that flying an airplane demanded complex coordination of hands and feet, emphasis was placed on factors like motor coordination and related psychomotor behavior. Among other measuring instruments in this area, and in line with this emphasis, was the Mashburn Serial Action Apparatus in which controls simulating those found in an airplane were manipulated by the subject, making it possible to measure certain aspects of behavior under standardized conditions. Experience with this instrument indicated that although when employed alone it was not wholly adequate as a predictor of success or failure in flight training, it was of sufficient value to warrant inclusion in selection test batteries.

This report presents a description of the original Mashburn apparatus as developed at Randolph Field, and a detailed discussion of a revised or modified form of this instrument made at Harvard University. The revision took the form of simplifying and rebuilding the original model with standard equipment obtainable from commercial manufacturers, thereby making it possible to reproduce the apparatus more easily and at a greatly reduced cost.

The report also presents results obtained on large groups of pilots during various stages of flying. The groups tested were 200 civilian pilots, 750 naval aviation cadets and 82 instructors at Pensacola, 400 student pilots in the Civilian Pilot Training Program in the Boston area, and 86 advanced C.P.T. students in training for the air ferries service. Data obtained with the original and revised apparatus are presented, along with a preliminary analysis of scores in relation to poor and successful pilots at various stages in their flying careers.

THE ORIGINAL MASHBURN SERIAL ACTION APPARATUS

Early studies of motor coordination and reaction time indicated that motor tests of a serial reaction type were more closely related to flying than were those measuring single reaction times. These studies led to the development of serial reaction tests such as the Thorne Reaction Time Test[1]

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[1]Thorne, F. H. and Snell, C. F. Some observations on the reaction time of student flyers. Milit. Surg., 1925, 56, 145-152.

and the O'Rourke Complex Coordinator[2] (developed in America), and the Reid Reaction Test[3] (developed in England). The Complex Coordinator was devised by O'Rourke in 1926. Washburn began using it in 1927 with U. S. Air Corps pilots at Randolph Field, Texas. On the basis of his experience he developed, in 1931, a new apparatus which was called the Washburn Automatic Serial Action Apparatus. Mr. Constable constructed the apparatus, and worked out the details of the wiring system. A complete description of the original model may be found elsewhere.[4, 5]

The apparatus was designed so as to roughly simulate the stick and rudder movements involved in flying a plane. The subject reacts to a continuous series of lights on the instrument panel by moving a set of controls operated by the hands and feet. The apparatus is automatic so that the correct response to one set of signals with stick and rudder automatically set up the succeeding signal until the entire series is completed. The subject's score is given in terms of the total time required to make the complete series of 40 settings.

The signal panel, mounted in an upright position in front of the subject, contains three double rows of parallel lights, thirteen in each row. One row in each set of lights is red and the other green. The red lights are signal lights that work automatically; the green lights are the response lights and are directly under control of the subject. Only one light is illuminated at a time in each row. The bottom row of lights corresponds to the movements of the rudder, the perpendicular row of lights to the elevator, and the top row of lights to the aileron. The controls are the type commonly used in the primary training planes. The three series of movements corresponding to the rudder, elevator, and aileron can be made independently of each other and do not necessarily demand the coordination of one with the others.

Several tests have been developed which are somewhat similar in principle to the Washburn Serial Action Apparatus. The one suggested by

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[2]Washburn, M. C. Psychology. In Randolph Field, Texas: School of Aviation Medicine, 1938, 176-179.

[3]Reid, and Sigrist. The Reid reaction apparatus. Picking out the qualities that go to make a good pilot. Flight. 1928, 20, 80-82.

[4]Washburn, M. C. Washburn automatic serial action apparatus for detecting flying aptitude. J. Aviation Med., 1934, 5, 155-160.

[5]_____. The complex coordinator as a performance test in the selection of military flying personnel. J. Aviation Med., 1934, 5, 145-154.

Williams and designed and constructed by Dr. E. J. Schuster of the Medical Research Council in England consists of a pilot's seat, adjustible rudder bar, stick, and illuminated test cabinet mounted about 2 feet in front of the pilot's seat.[6] A spot of light, activated by a grooved disc which revolves inside the cabinet, moves in a definite but irregular course across the glass screen for a period of 100 seconds. The candidate has to neutralize the irregular movements of this spot of light and keep it centered on the screen, by means of the rudder bar for lateral deviations, and the control column for vertical deviations. At the same time certain distractions, such as a red and white light in front of the cabinet, or a bell and buzzer, have to be counteracted as quickly as possible by moving a lever with the left hand. A system of differential gearing records the score on four separate discs for leg and arm movements, reaction to distractions, and total score respectively. Two trial runs are given and the scores are recorded on the third run. This test gives a numerical record of the candidate's "ham-handedness" or "lead-footedness." No recent data are available which have been obtained with this apparatus, but the preliminary results were promising.

In the revision of the Washburn test described in this report no attempt was made to change the basic principles of the original apparatus. For example, one limitation of the test is that the three adjustments (rudder, aileron, and elevator) can be made independently and thus the ability of the subject to make coordinated movements of several controls is not directly measured. The present revision is merely an attempt to provide an instrument which would satisfy three important requirements in an apparatus test intended for wide use in a pilot selection program: (1) it should be fairly inexpensive to reproduce and simple in construction; (2) it must provide accurate data, comparable from one instrument to another; and (3) it must be rugged in construction and easily maintained while in use. The present revision seems to satisfy these three requirements, especially in that it uses standard parts available from commercial manufacturers.

THE REVISED SERIAL REACTION TIME APPARATUS

Following is a detailed description of the Revised Serial Reaction Time Apparatus. Photostats of mechanical drawings of the apparatus are also presented in Figures 1 to 6.[7]

A. The Completely Assembled Apparatus.

The completely assembled apparatus giving the various over-all dimensions of the wooden framework, chair, stick, rudder bar, and light panel

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[6] Whittingham, H. E. Medical research and aviation. J. Royal Navy Med. Serv., 1940 (Jan.), 15-24.

[7] In the photostated drawings of the apparatus, some of the dimensions have been omitted so as to make the drawings more easily interpreted. If construction of a model is contemplated, the original drawings should be obtained.

is shown in Fig. 1. The base and upright portions are constructed of plywood. This may be separated for shipment by removing wing nuts in the lower part of the upright portion and disconnecting the electrical cables by means of the large 15 point plugs. The seat is adjustable on the platform so that each subject can comfortably reach the stick and rudder bar.

The apparatus functions as follows: The movements of the stick and rudder bar (Fig. 1) operate electrical switches mounted directly beneath these controls. Electrical cables connected to these switches run to the top metal cabinet of the upright wooden frame and are connected to the light panel and various parts of the electrical circuit (Fig. 2, and Appendix A-2). Movements of the stick from side to side illuminate the green lights in the arc across the top of the panel (Fig. 2). Movements of the stick forward and backward light the green ones in the upright middle row. When all three green lights match the illuminated red lights, they close the circuit shown in Wiring Plan No. 2 (Appendix A-1). Upon completion of this circuit the main stepping relay is activated which sets up a new pattern of red lights. These 13 patterns have been arbitrarily chosen and are listed in Appendix A-2, Section A. The numbers and letters listed in Appendix A-2, Section B, indicate the electrical connections necessary to complete the electrical circuits to various parts of the apparatus.

One of the most important alterations in the revised apparatus consists in assembling the stimulus lights, relays, transformer, and buzzer in a metal cabinet as a unit. This cabinet can be purchased from the Par-Metal Products Company (Appendix C).

B. The Light Panel Assembly.

The dimensions and arrangement of the light panel assembly are shown in Fig. 2. The five lights along each side play no part in the functioning of the test. These lights are connected with the main switch and remain illuminated during the test.[8] The arrangement of the parallel row of red and green lights is shown in Appendix A-1, X. It is lettered and numbered for convenience in showing the method of wiring. The pilot lights and sockets which are mounted behind the windows or jewels (Fig. 2) are secured to a frame according to dimensions given in Fig. 3. The positions of condenser, vacuum tube, and relays are shown in Fig. 4. The apparatus is wired as a unit and mounted in the upper part of the light panel box.

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[8] Editor's Note. These "distraction" lights were added to the revised model of the Washburn, although they were not consistently used in the testing situation. An experimental determination of the effect of these lights on the performance of subjects during the testing procedure, has recently been made. See: Wance, R. D., Buxton, C. E., Spence, K. W. The effect of distraction lights upon performance on the Washburn serial coordination test. Washington, D. C.: U.S.A. Division of Research, Report No. 29, April 1944.

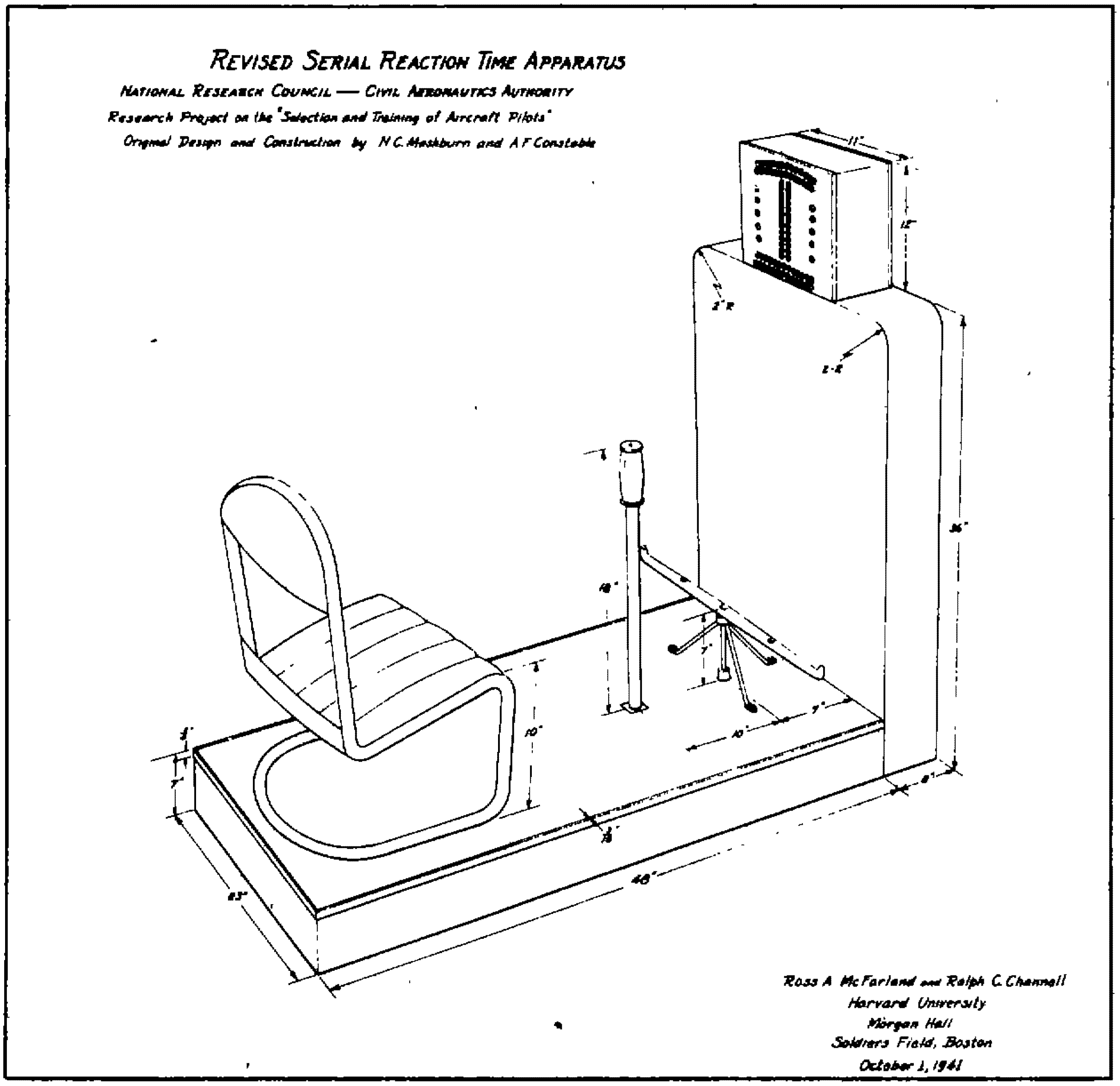
REVISED SERIAL REACTION TIME APPARATUS
NATIONAL RESEARCH COUNCIL — CIVIL AERONAUTICS AUTHORITY
Research Project on the "Selection and Training of Aircraft Pilots"
Original Design and Construction by N.C. Mashburn and A.F. Constable
11"
12"
36"
10"
7"
48"
Ross A. McFarland and Ralph C. Channell
Harvard University
Morgan Hall
Soldiers Field, Boston
October 1, 1941

Figure 1

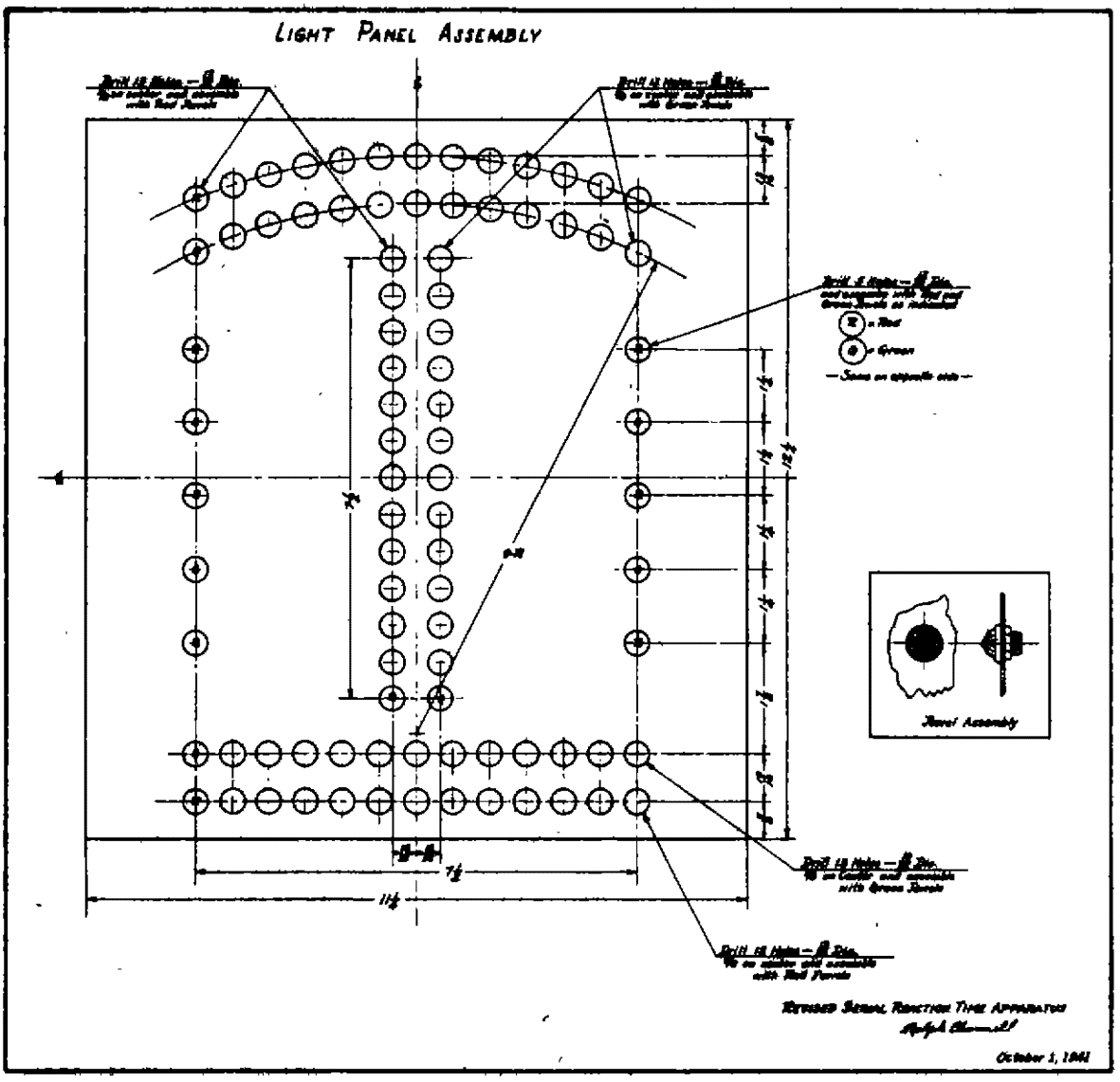

Figure 2

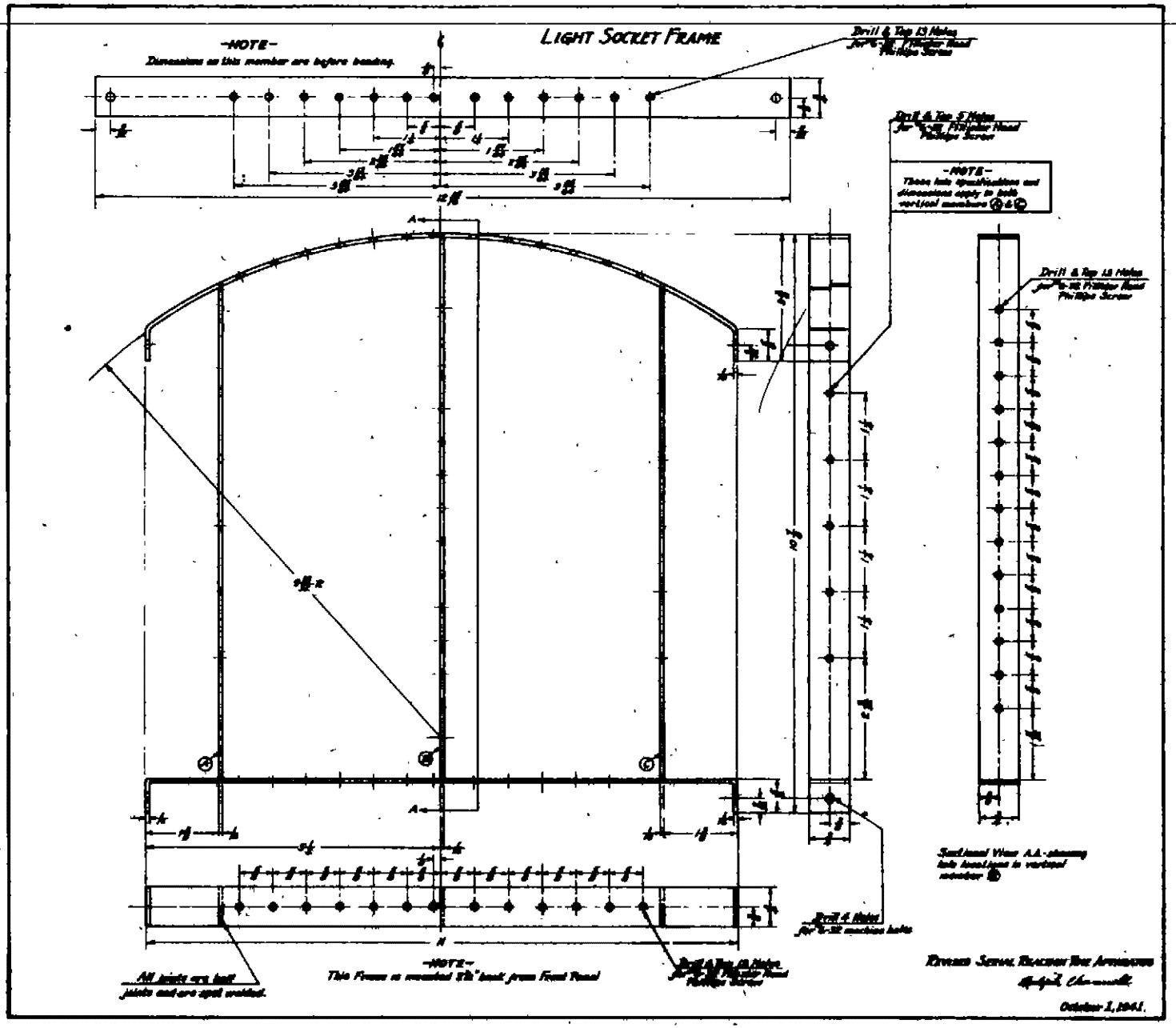
LIGHT SOCKET FRAME
-NOTE-
Dimensions on this member are before bending.
Drill & Tap 13 Holes
-NOTE-
Drill & Tap 13 Holes
Sectional View A-A showing hole locations in vertical member
Drill 4 Holes
All joints are butt joints and are spot welded.
-NOTE-
This Frame is mounted 1/8" back from Front Panel
October 1, 1941.

Figure 3

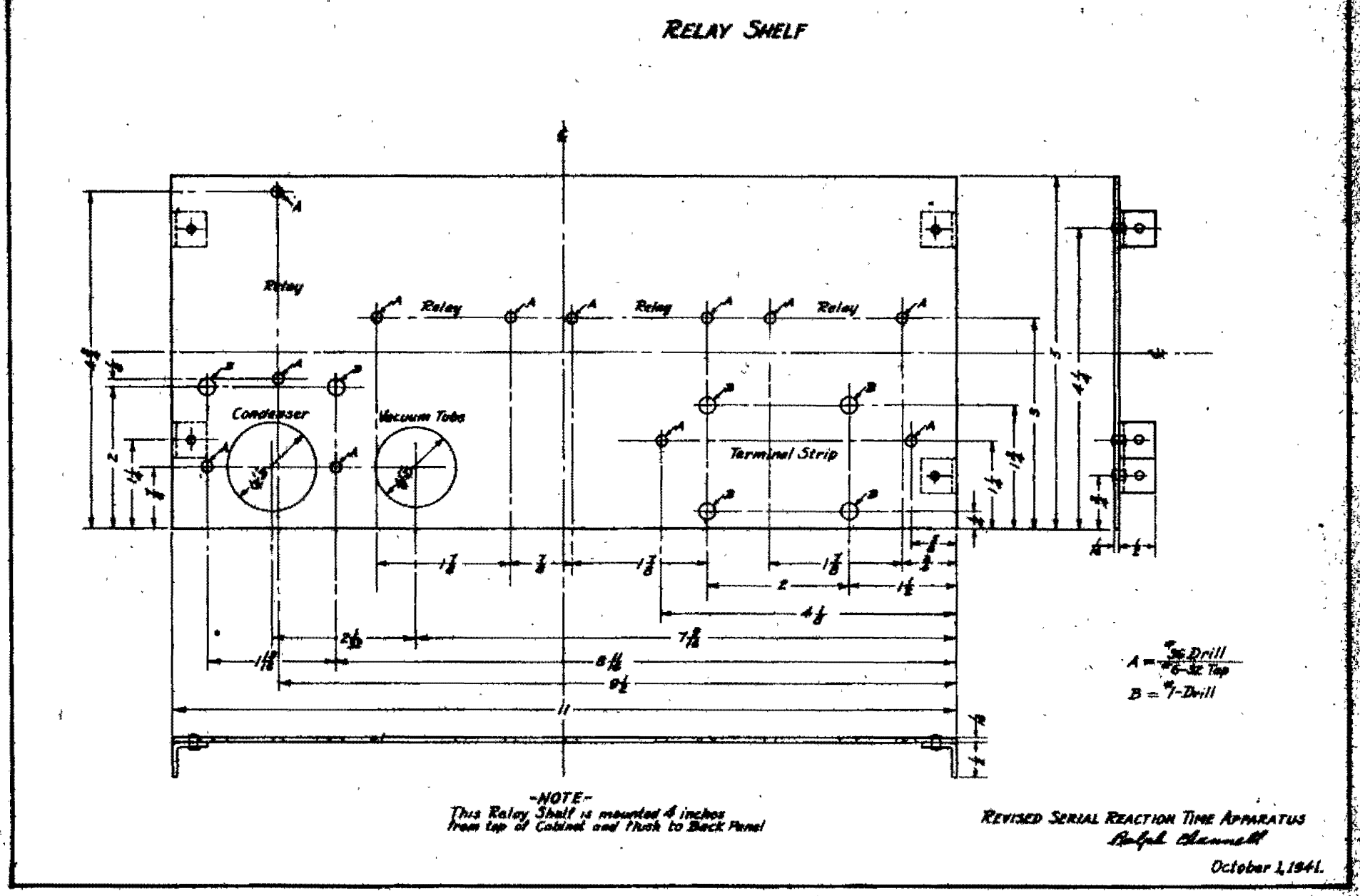
RELAY SHELF
Relay
Relay
Relay
Relay
Relay
Condenser
Vacuum Tube
Terminal Strip
A = #36 Drill / 6-32 Tap
B = #7-Drill
-NOTE-
This Relay Shelf is mounted 4 inches from top of Cabinet and flush to Back Panel
REVISED SERIAL REACTION TIME APPARATUS
Rudyard Clamwell
October 1, 1941.

Figure 4

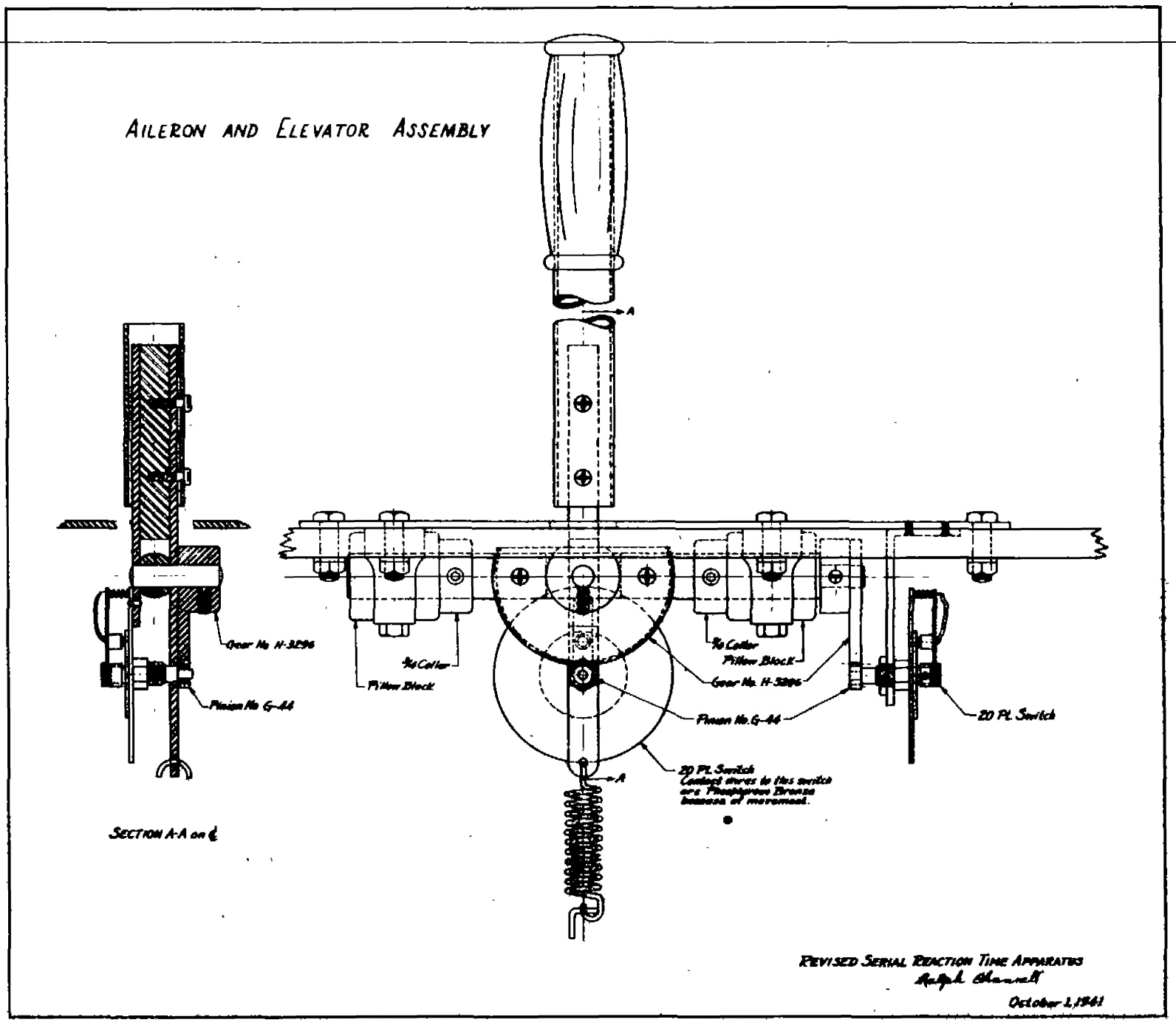
AILERON AND ELEVATOR ASSEMBLY
A
Gear No. H-3296
Pinion No. G-44
SECTION A-A on ℄
¾ Collar
Pillow Block
¾ Collar
Pillow Block
Gear No. H-3296
Pinion No. G-44
20 PL Switch
20 PL Switch
Contact wires to this switch are Phosphorus Bronze because of movement.
A
REVISED SERIAL REACTION TIME APPARATUS
Ralph L. Channell
October 1, 1941

Figure 5

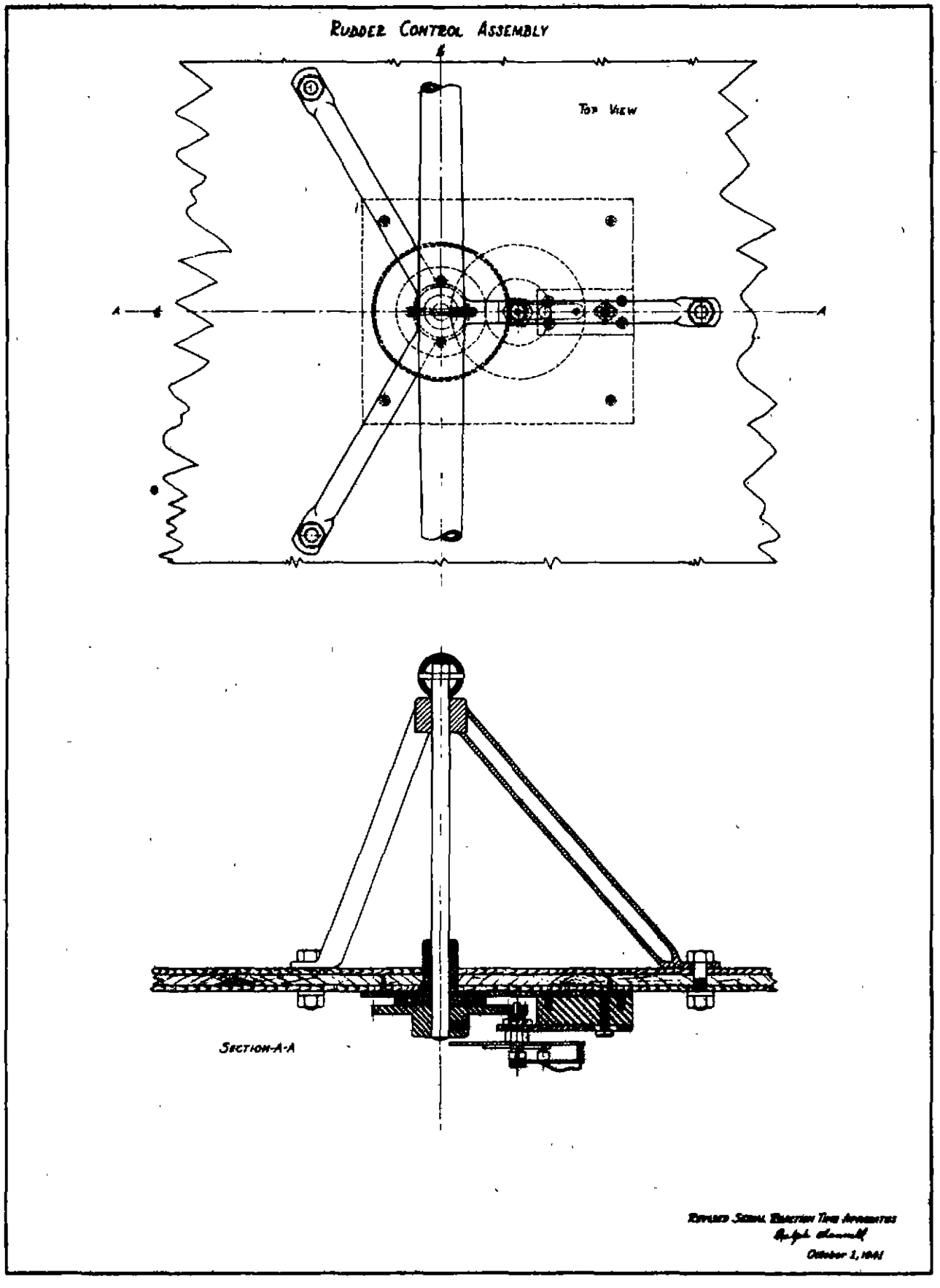
RUDDER CONTROL ASSEMBLY
TOP VIEW
A
A
SECTION-A-A
October 1, 1941

Figure 6

[illegible] Mechanical Assembly.

A common terminal board (Appendix A-1, [illegible]) is installed in the rear part of the light panel box to facilitate the connection or disconnection of the various units within the limited space of the cabinet. The interconnections between X and Y are made according to the stimulus patterns of the red lights, and the sequence of these patterns is listed in Appendix A-2, Section 4. The stepping relay which sets up the sequence of stimulus patterns is shown schematically in Appendix A-1, S.

Interconnections between the points in each bank of this stepping relay (S) and the common terminal (Y) are also listed in Appendix A-2, Section B. In accordance with each stimulus pattern, the subject must move the controls so as to complete the electrical circuits which set up the next pattern. The switches operated by the controls are diagramed in Appendix A-1, Z, and the interconnections between these switches and the common terminal board (Y) are shown in Appendix A-2, Section C.

D. The Aileron and Elevator Assembly.

Fig. 5 shows a side view and a front view of the mechanical operation of the aileron and elevator assembly. The elevator contact switch is a movable unit located directly beneath the stick, rotating in an arc around a segment of a large gear (H-3296). A small pinion gear rotates the arm of the switch, the contact points of which are wired according to Wiring Plan No. 1, Appendix A-1. Only 13 points of the standard 20 point switch are used. Since the elevator switch is movable, the points are wired with phosphorous bronze to prevent leakage. The aileron switch is stationary and is shown on Fig. 5. The arm of this switch is rotated by a small pinion turned by a segment of a larger gear. The connections from this switch are shown in Wiring Plan No. 1.

E. The Rudder Control Assembly.

Figure 6 shows the top and side view of the rudder control assembly. The 20 point contact switch shown in Fig. 6 is connected according to Wiring Plan No. 1, Appendix A-1.

F. Description of Standard Parts.

Standard gears have been used in the stick and rudder control assemblies. The small gears connected to the rotating switches are cut by lathe from Boston Gear Pinion Rod, which has twelve teeth thirty-two pitch with three sixteenth-inch face. These small gears are drilled to size and mounted on the shaft of the rotary switch. The large gears for the rudder and the aileron control must be cut so as to clear the assembly plate.

The 20 point rotary electrical switches are obtainable from the Guardian Electric Company (Appendix C). Only 13 points are used but the movement produced by the controls fits very well to the sector set up by these

20 point switches. In ordering the rotary switches it should be stated that shafts one-half inch longer than standard are desired.

In making the electrical connections to the elevator control switches, phosphorous bronze wire must be used. This wire should extend away from the contact points for approximately one foot because the switch is cradled and must be free to move. This movement wears out ordinary copper wire connections.

The main stepping relay is a Series R stepping relay, 26 point contact, (four bank), made to specifications by the Guardian Electric Company of Chicago, Illinois. The coil is designed for 110 volts A. C. 60 cycle current (Appendix C).

In making the electrical interconnections all units are wired to a central terminal strip which permits the removal of any unit for repair or replacement. Fourteen wire cables with connection plugs are used to connect the switches with the control cabinet. This enables one to separate the lower wood base from the upright part to facilitate the shipment of the apparatus.

In the red light stimulus pattern there are 13 different combinations as designed in the original Serial Reaction Time apparatus. Since this arrangement may be considered standard, the buzzer has been placed on the thirteenth setting and the stepping relay reduced to 26 points instead of the original forty. It was originally planned to reduce this stepping relay to 13 points but a relay of this type was found to be impracticable. A 26 point stepping relay was used in its place.

The time delay for the master relay is obtained by the use of a vacuum tube and condenser as shown in Wiring Plan No. 2, Appendix A-1. All interconnections are listed in Appendix A-2.

G. Stability of the Apparatus.

One model of this apparatus was in almost constant use for over a year under the supervision of a trained technician. No difficulties were encountered. In the case of two similar models slight adjustments were necessary after shipment and during routine testing. It should be kept in mind that this equipment has a complex wiring and relay system requiring the usual care and treatment given such instruments.

H. List of Manufacturers of Standard Parts.

In Appendix C the name and description of the parts are listed along with the name and address of the manufacturer, the quantity required per unit, and the catalog number.

A. Preliminary Findings at Randolph Field.

In 1931, cadets at Randolph Field were tested with the original Mashburn Apparatus.[10] The subjects chosen for the study were limited to second lieutenants and flying cadet trainees. The test scores of the 789 cadets who were graduated and the 924 cadets who were eliminated for the reason "failure to make satisfactory progress in flying training" were compared. The scores of the total group of 1713 cases ranged from 2 minutes and 50 seconds (2:50) to 14 minutes.

A diagram showing the relationship of scores on this apparatus to graduation is shown in Fig. 7. There were 35 students in the group whose scores fell in the top interval and 68 students whose scores fell in the lowest interval.[11] The training records of these two groups were as follows: Of the 35 in the top interval, 27 graduated and 8 failed, or 77% succeeded; while in the lowest interval, 11 graduated and 57 were "washed out," or 84% failed. The author concluded that the possibility of obtaining trained pilots from a group of applicants whose scores fell in the upper class interval was about five times as great as the probability of obtaining a trained pilot from a group whose scores fell in the lowest class interval.

No further statistical analysis was made from the data although the results appear to indicate a fairly high relationship between test scores and success in flying, as indicated in Fig. 7. A further analysis of results obtained with this apparatus on aviation cadets at Randolph Field has been reported by Glenn.[12]

B. Findings Obtained in This Investigation on both the Original and Revised Forms of the Mashburn.

More than 2,800 pilots at various stages in their flying careers were tested in this investigation. They varied in age from 18 to 47 years, and in flying experience from beginning students to civil airline pilots of many thousands of hours of flying time. The initial experiments were carried out on civilian pilots with a model of the original Mashburn apparatus

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[9]Editor's Note. A more extended treatment of the results obtained with the Pensacola subjects will be presented in subsequent reports dealing with the Pensacola Study of Naval Aviators.

[10]Mashburn, N. C. op. cit. 179-186. (Footnote 2.)

[11]The individuals scoring less than 3 minutes, and above 8 minutes and 16 seconds, were so few in number that they were grouped in the top and lowest intervals indicated in the chart.

[12]Glenn, Charles R. A preliminary report on a performance test for flying. J. Aviation Med., 1935, 6, 14-19.

Washburn Scores in Minutes and Seconds	N	Graduated	Washouts
3:00 - 4:00	35	27 = 77%	8 = 23%
4:01 - 4:15	53	38 = 72%	15 = 28%
4:16 - 4:30	59	42 = 71%	17 = 29%
4:31 - 4:45	107	63 = 59%	44 = 41%
4:46 - 5:00	132	78 = 59%	54 = 41%
5:01 - 5:15	139	82 = 59%	57 = 41%
5:16 - 5:30	174	92 = 53%	82 = 47%
5:31 - 5:45	146	73 = 50%	73 = 50%
5:46 - 6:00	151	64 = 42%	87 = 58%
6:01 - 6:15	124	50 = 40%	74 = 60%
6:16 - 6:30	118	47 = 40%	71 = 60%
6:31 - 6:45	116	45 = 39%	71 = 61%
6:46 - 7:00	75	20 = 27%	55 = 73%
7:01 - 7:15	76	25 = 33%	51 = 67%
7:16 - 7:30	46	15 = 33%	31 = 67%
7:31 - 7:45	34	7 = 21%	27 = 79%
7:46 - 8:00	37	4 = 11%	33 = 89%
8:01 - 8:15	23	6 = 26%	17 = 74%
8:16 +	68	11 = 16%	57 = 84%
	1713	789 Graduated	924 W. O.

Figure 7

RELATION BETWEEN WASHBURN SERIAL MOTION APPARATUS SCORES AND SUCCESS IN FLIGHT TRAINING AT RANDOLPH FIELD, TEXAS (1931)*

*Adapted from results presented in Table 3 of Washburn, M. C., op. cit. (Footnote 2)

obtained from Randolph Field.[13] The same apparatus was used in the study of student pilots in the Civilian Pilot Training Program in the Boston area and also in the study of naval cadets and officers at the Naval Air Station, Pensacola, Florida. The revised apparatus was used in the Fall and Spring Programs of 1940-41 with the C.P.T. student pilots in the Boston area.

TABLE 1

MEANS, STANDARD DEVIATIONS, AND RANGES OF SCORES FOR PILOTS FROM 18 TO 47 YEARS OF AGE
(N = 1556)

Subjects	N	Age Range	Mean Flying Hours	Mean	S.D.	Range
1. Civil Airline Pilots	201	20-47	5,600	5.78	0.56	(3.20- 9.03)
2. Control Group of Non-Pilots	53	20-47	0	6.97	1.13	(4.52-11.33)
3. Pensacola Cadets and Officers						
Classes 147-151	372	21-27	10	5.97	1.03	(3.90-10.67)
Classes 152-159	378	21-27	10	5.60	0.85	(3.28-10.15)
4. Pensacola Instructors	82	25-37	1,500	5.95	0.82	(4.37- 7.63)
5. C.P.T.P. Student Pilots						
Primary 1939-40	216	18-21	0	5.40	1.00	(3.40- 8.50)
Primary Spring Term, 1941	81	18-21	0	5.29	0.95	(3.50- 8.60)
*Primary Fall Term, 1941	87	18-22	0	5.30	1.10	(3.30- 9.90)
6. *Flight Officers Training School, Northeast Airlines	86	23-27	200	4.54	-	(3.03- 7.20)

*Revised Apparatus

Table 1 shows the number of pilots in each group and the ranges, means, and standard deviations of the scores for the various groups given in minutes and fractions of a minute. It is interesting to note that the means for the three groups of candidates for flight training in the C.P.T. Program are very similar. In the Fall (1941) group the revised apparatus was used. It is of interest also that the student pilots in the C.P.T. course made slightly better mean scores than the naval aviation cadets and the civilian pilots. As a group they were not only younger, but probably more highly motivated since the test was given at the very beginning of their course of training.

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[13]The authors are indebted to the Commandant, School of Aviation Medicine, Randolph Field, for the use of this equipment during 1939-40.

c. Civil Airline Pilots. [illegible] obtained with this apparatus for the 201 civil airline pilots are shown in Table 2.[14] The mean reaction time for the entire group was 5.78 minutes. In a control group of 53 non-fliers, comparable in education and age, the mean was 6.97 minutes. Comparison of the results obtained in this study with the data from Randolph Field show that the civil pilots tend to score within the range of the more successful pilots. For example, the 80 civil airline pilots in the first two age groups, i.e., those between the ages of twenty to thirty years, comparable in age to the ones at Randolph Field, made a mean score of 5.21 minutes. This is within the range where 60 per cent were successful in passing the training courses at Randolph Field. The older pilots tended to make poorer scores. This may offer an additional proof in favor of the test since it is known that complex reaction time increases with age. This relationship holds despite the fact that the older pilots have had more flying time.

TABLE 2

MEANS AND STANDARD DEVIATIONS OF CIVIL AIRLINE PILOTS VARYING IN AGE FROM 20 TO 47 YEARS, AND IN FLYING TIME FROM 800 TO 12,500 HOURS

Group	N	Mean Flying Hours	Mean Number of Settings Completed During Each Min. of Test					Mean in Mins.	S. D.
			1	2	3	4	5		
20-24 years	21	800	7.9	7.8	7.1	8.0	6.8	5.28	0.72
25-29 years	59	2,500	8.8	7.7	7.9	7.5	6.8	5.18	1.03
30-34 years	70	5,500	7.8	6.7	7.0	7.0	6.6	5.75	0.92
35-39 years	26	7,000	7.2	6.7	6.3	6.7	6.4	6.07	0.88
40-47 years	25	12,500	6.7	6.4	6.5	5.7	6.1	6.63	1.08
Mean	201		7.7	7.1	7.0	7.0	6.5	5.78	0.93
Control Group 24-48 years	53	00	7.0	6.9	7.0	6.8	6.7	6.97	1.22

The practice effects in the test, especially if taken on succeeding days, are fairly large. This is controlled by allowing each person only eleven practice settings before the test is begun. No scores are included for subjects who had previous experience with the apparatus. The average number of successful settings per minute, as shown in Table 2, indicates

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[14] McFarland, R. A., Graybiel, A., Liljenerantz, E., and Tuttle, A. D. An analysis of the physiological and psychological characteristics of 200 civil airline pilots. J. Aviation Med., 1939, 10, 160-210.

that the improvement from minute to minute during the first run of forty settings is not large. In the groups of civilian pilots, the number of successful settings per minute actually decreased during the course of the test. In many cases, the largest number of settings were made during the first minute of the test. This did not always hold true in the groups of student pilots unfamiliar with the motor acts involved in flying.

2. Aviation Cadets and Instructors at Pensacola. In Table 3 the distribution of scores is shown for the successful and unsuccessful aviation cadets at Pensacola for classes 147 to 151, and in Table 4 for classes 152 to 164.

TABLE 3

THE DISTRIBUTIONS OF SCORES FOR SUCCESSFUL AND UNSUCCESSFUL PENSACOLA AVIATION CADETS IN CLASSES 147-151

Part 1			Part 2		
Raw Score	Successes	Washouts	Raw Score	Good Pilots	Washouts Plus Board Appearances
3.7- 4.1	5		3.7- 4.1	5	
4.2- 4.6	17		4.2- 4.6	17	
4.7- 5.1	71	3	4.7- 5.1	67	7
5.2- 5.6	81	8	5.2- 5.6	72	17
5.7- 6.1	66	8	5.7- 6.1	60	14
6.2- 6.6	35	13	6.2- 6.6	31	17
6.7- 7.1	28	11	6.7- 7.1	27	12
7.2- 7.6	17	4	7.2- 7.6	13	8
7.7- 8.1	10	2	7.7- 8.1	7	5
8.2- 8.6	3	1	8.2- 8.6	3	1
8.7- 9.1	0	1	8.7- 9.1	0	2
9.2- 9.6	1	1	9.2- 9.6	1	1
9.7-10.1	1	0	9.7-10.1		1
10.2-10.6		1	10.2-10.6		1
N	335	53	N	303	86
Mean	5.83 ± .05	6.59 ± .15	Mean	5.78 ± .05	6.50 ± .12
Sigma	0.96 ± .04	1.08 ± .10	Sigma	0.92 ± .04	1.14 ± .09
Range	3.87-10.13	4.95-10.67	Range	3.87-9.72	4.70-10.67
Critical Ratio (Means)		4.78	Critical Ratio (Means)		5.38
Critical Ratio (Sigmas)		1.03	Critical Ratio (Sigmas)		2.32
Chi-squared		P = <.01	Chi-squared		P = <.01

In Part 1 of the table the Successes (those who completed the course although some may have had one or more appearances before the Commandant's Advisory Board) are shown in relation to the Washouts (those who were dropped from training because of inaptitude in flying). In Part 2 of

the table the scores of the Good Pilots (those successful pilots who had never had a board appearance) are shown in comparison with the Washouts plus those "successful" pilots with board appearances.

TABLE 4

THE DISTRIBUTIONS OF SCORES FOR SUCCESSFUL AND UNSUCCESSFUL PENSACOLA AVIATION CADETS IN CLASSES 152-164

Part 1			Part 2		
Raw Score	Successes	Washouts	Raw Score	Good Pilots	Washouts Plus Board Appearances
3.0- 3.3	2		3.0- 3.3	2	
3.4- 3.7	7	1	3.4- 3.7	6	2
3.8- 4.1	9	0	3.8- 4.1	9	0
4.2- 4.5	28	4	4.2- 4.5	25	7
4.6- 4.9	51	7	4.6- 4.9	51	7
5.0- 5.3	59	4	5.0- 5.3	51	12
5.4- 5.7	64	11	5.4- 5.7	54	21
5.8- 6.1	39	14	5.8- 6.1	36	17
6.2- 6.5	27	10	6.2- 6.5	21	16
6.6- 6.9	25	6	6.6- 6.9	17	14
7.0- 7.3	8	3	7.0- 7.3	8	3
7.4- 7.7	5	3	7.4- 7.7	5	3
7.8- 8.1	5	5	7.8- 8.1	5	5
8.2- 8.5	2	2	8.2- 8.5	2	2
8.6- 8.9	2	0	8.6- 8.9	2	0
9.0- 9.3	0	2	9.0- 9.3		2
9.4- 9.7	0		9.4- 9.7		0
9.8-10.1	1		9.8-10.1		1
N	334	72	N	294	112
Mean	5.56± .05	6.19± .14	Mean	5.52± .06	6.08± .11
Sigma	0.99± .04	1.16± .10	Sigma	0.98± .04	1.12± .08
Range	3.28-10.15	3.75- 9.20	Range	3.28- 8.70	3.75-10.15
Critical Ratio (Means)		4.29	Critical Ratio (Means)		4.65
Critical Ratio (Sigmas)		1.67	Critical Ratio (Sigmas)		1.65
Chi-squared		P = <.01	Chi-squared		P = <.01

It should be noted that in both Tables 3 and 4 the critical ratios are large enough to show that the differences between the mean scores of the two groups are probably not due to chance.[15] Likewise the probability as

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[15] A critical ratio of 3.00 represents a highly significant difference between the measures, since it indicates that only once in 1000 times would a difference in the observed direction as great as, or greater than, the observed difference be obtained by chance if the true difference were zero. A critical ratio of 2.00 is sometimes considered as approaching significance, since the difference would occur by chance only 2 times in 100.

shown by the chi-square test is less than one chance in 100 that the differences in the distributions are due to chance fluctuations in random sampling.

In Table 5 the combined distributions of classes 147 to 151 and classes 159 to 164 are based on standard scores, the class units being in intervals of five-tenths of one standard deviation from the mean of the total group.

TABLE 5

THE DISTRIBUTIONS OF STANDARD SCORES FOR SUCCESSFUL AND UNSUCCESSFUL PENSACOLA AVIATION CADETS IN CLASSES 147 - 164

Part 1			Part 2		
Standard Score	Successes	Washouts	Standard Score	Good Pilots	Washouts Plus Board Appearances
3.0	2		3.0	2	
2.5	7	1	2.5	6	2
2.0	14	0	2.0	14	0
1.5	45	4	1.5	42	7
1.0	122	10	1.0	118	14
.5	140	12	.5	123	29
.0	130	19	.0	114	35
- .5	74	27	- .5	67	34
-1.0	55	21	-1.0	48	28
-1.5	42	10	-1.5	30	22
-2.0	18	5	-2.0	15	8
-2.5	8	4	-2.5	8	4
-3.0	5	6	-3.0	5	7
-3.5	3	3	-3.5	3	3
-4.0	3	0	-4.0	2	1
-4.5	0	3	-4.5		3
-5.0	0		-5.0		0
-5.5	1		-5.5		1
N	669	125	N	597	198
Mean	-.09 ± .04	-.70 ± .12	Mean	+.14 ± .04	-.58 ± .09
Sigma	1.11 ± .03	1.30 ± .08	Sigma	1.08 ± .03	1.30 ± .07
Critical Ratio (Means)		6.35	Critical Ratio (Means)		7.06
Critical Ratio (Sigmas)		2.18	Critical Ratio (Sigmas)		3.01
Chi-squared		P = < .01	Chi-squared		P = < .01

An examination of the critical ratios between the means of the successful and unsuccessful cadets shows that the probability of the difference between the means being a chance one is greatly decreased by combining the two groups of classes.

Tables 3, 4, 5, and 7 also present the standard deviations (sigmas) of the distributions. The sigmas of the "poorer" groups are larger in all comparisons but only one of the critical ratios reaches 3.00. Five of the eight critical ratios are above 2.00, however, suggesting a trend in this direction.[16]

In Table 6 the distribution is shown for a group of instructors of flight training at the Naval Air Station, Pensacola, Florida. The mean score of this group is slightly poorer than the means of the successful cadets. This may have been due to a difference in motivation at the time of taking tests and the influence of the age factor. The mean for the group of instructors does not differ greatly from that of the civil airline pilots of comparable age (Table 2).

TABLE 6

DISTRIBUTION OF SCORES FOR 82 AVIATION INSTRUCTORS VARYING IN AGE FROM 25 TO 37 YEARS

Raw Score	N
4.25-4.49	4
4.50-4.74	1
4.75-4.99	8
5.00-5.24	7
5.25-5.49	6
5.50-5.74	7
5.75-5.99	10
6.00-6.24	9
6.25-6.49	7
6.50-6.74	7
6.75-6.99	5
7.00-7.24	6
7.25-7.49	3
7.50-7.74	2
7.75-7.99	
	82

Mean	5.95 ±	.09
Sigma	0.82 ±	.06
Range	4.37 -	7.62

[16]The authors are indebted to Dr. P. S. Lawrence for assistance in the analysis of the data in Tables 3 to 7, inclusive, and to Dr. J. W. Dunlap for the statistical analysis in Table 8.

In comparing the results obtained on aviation cadets at Pensacola (Table 5) with those reported by Washburn from Randolph Field (Fig. 7), several differences between the groups should be kept in mind. At Randolph Field, approximately 55 per cent failed, while at Pensacola only 15-20 per cent were dropped from training. The lower percentage of failures at Pensacola may have been due to previous selection in flight training at the Naval Reserve Air Bases. Also there may have been a shift in attitude in eliminating pilots due to the proximity of the war. In spite of these differences, however, there is a striking relationship between the findings in the two studies of naval and military aviation cadets.

3. C.P.T. Student Pilots in the Primary Course. The results obtained with student pilots in the C.P.T. Program in the Boston area are shown in Table 7. In Part 1 of this table the selection of Good and Poor pilots is

TABLE 7

THE DISTRIBUTIONS OF SCORES FOR TWO GROUPS OF C.P.T. CANDIDATES FOR FLIGHT TRAINING IN THE BOSTON AREA

Part 1 (1939-40)

Raw Score	Good Pilots	Poor Pilots
3.15-3.64	1	
3.65-4.14	2	
4.15-4.64	14	2
4.65-5.14	11	5
5.15-5.64	9	9
5.65-6.14	8	6
6.15-6.64	2	5
6.65-7.14		1
7.15-7.64		3
7.65-8.14		2
8.15-8.64		2
N	47	35
Mean	5.01± .10	6.04± .18
Sigma	.69± .07	1.08± .12
Range	3.72- 6.33	4.28- 8.77
Critical Ratio (Means)		5.00
Critical Ratio (Sigmas)		2.65
Chi-squared		P = <.01

Part 2 (1940-41)

Raw Score	Good Pilots	Poor Pilots
3.5-3.9	5	
4.0-4.4	13	1
4.5-4.9	13	5
5.0-5.4	10	11
5.5-5.9	3	3
6.0-6.4	4	2
6.5-6.9	1	4
7.0-7.4		0
7.5-7.9		3
8.0-8.4		2
8.5-8.9		1
N	49	32
Mean	4.84± .11	5.97±
Sigma	.74± .08	1.21±
Range	3.52- 6.57	4.43- 8.65
Critical Ratio (Means)		4.76
Critical Ratio (Sigmas)		2.78
Chi-squared		P = <.01

based on a combination of time to solo and time to certification for a pilot's license. The good pilots soloed in less than 8.5 hours and were certified in less than 36.5 hours. The time to solo for the poor pilots was 9.5 or more hours of dual instruction and they obtained their certificates in 39.0 or more hours. The student pilots who fell in between these

two extremes are not shown in the distributions. It is interesting that there is a marked and statistically significant displacement of the poor pilots toward the lower scores. In Part 2 of Table 7 the entire 1940-41 group appears in the two distributions. The students were divided into good and poor pilots on the basis of instructors' ratings. Five of the poorer students were actually "washed out" because of poor motor aptitude. The ratings were not made known to those carrying out the experiment in the laboratory, and the findings of both the instructors and experimenters were not tabulated until the end of the study. Only one of the so-called Good Pilots would have been eliminated if the poorest ten had been dropped on the basis of poor scores in this test before they started their flight training.

The data obtained on 87 candidates in the 1941 Fall C.P.T. Program in the Boston area are shown in Table 8. The revised Serial Reaction Time Apparatus was used in this study. The mean score for the group of 87 pilots for 40 settings was 5.3 minutes. This value is similar to that obtained with the apparatus from Randolph Field on similar groups of C.P.T. students in the Boston area (Table 1).

TABLE 8

THE MEAN AND STANDARD DEVIATIONS AT SUCCESSIVE INTERVALS (SETTINGS) OF THE TEST. CORRELATIONS ARE SHOWN BETWEEN THE VARIOUS TRIALS OR SETTINGS. (N = 87)

(The Revised Apparatus was Used in Obtaining These Data)

		Settings				Differences		
	Number	13	26	39	40	26-13	39-26	40-39
	Mean	1.8	3.6	5.2	5.3	1.7	1.6	0.15
	Sigma	0.5	0.8	1.1	1.1	0.4	0.3	0.06
Settings	13		.950*	.930*	.938*	.766	.730	.312
"	26			.979*	.978*	.926*	.764	.340
"	39				.998*	.906*	.874*	.340
"	40					.906*	.870*	.384*
Difference	26-13						.697	.034
"	39-26							.234

[17]For explanation of asterisks, see text, page 23.

In the revised apparatus, as in the original model, there are only 13 different settings or stimulus patterns. During the test there are 13 settings repeated three times, and in the same sequence. One additional setting is given to complete the forty which make up the test. The first thirteen are strictly comparable to the second and third series of 13 for they exactly reproduce each other. Table 8 shows, in the columns headed "Settings," the mean number of minutes at the end of each 13 settings. It also shows, in the columns headed "Differences," the total time necessary to complete the second and third series of 13, and the time for the 40th trials. Thus the time for the first series (13) was 1.8; the time for the second (26-13) was 1.7; and for the third (39-26), 1.6.

The correlations in Table 8 are of two kinds. An asterisk marks the correlations of time up to an earlier setting in the test with the total time up to a later setting (including the earlier time). These correlations are of interest as showing the extent to which scores of a 13-setting or 26-setting test would predict the scores of the longer tests. The first 26-settings appear to predict the scores on the total test with great accuracy (r = .978).[18] Correlations not marked with an asterisk are those in which the times of one series do not include the times of another. Thus the correlation of the first series with the second is .766; with the third it is .730. The correlation of the second with the third is .697. The correlation of the first two series (26) with the third (39-26) is .764. These figures give an indirect indication that the reliability of the test is fairly high. They are not comparable, however, to odd-even or repeat measures of reliability, inasmuch as they may be affected by differences in rate of learning.[19]

4. Flight Officers Training School Pilots (Northeast Airlines). The test was given as a part of a comprehensive aptitude and medical examination as a basis for enrollment in the Advanced Flight Officers Training Course at the Northeast Airlines for those who were to serve later as ferry pilots for Pan American Airways, Africa, or P.A.A. Air Ferries. The pilots tested had completed the Primary, Secondary, Cross Country, and Instructor Courses of the C.P.T. Programs of the C.A.A., and each averaged 200 hours of flying time. The conditions under which the tests were given were excellent in that none of the pilots had previous experience with the test. They understood further that the results had some meaning in relation to being qualified for the course. The mean score for this group was 4.54 minutes, the best obtained by any group of aviation subjects (Table 1). This may be due to the fact that they were highly selected young pilots

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[18] This correlation cannot be considered as a reliability coefficient since the time for the first 26 settings is a part of the total score with which it was correlated.

[19] Editor's Note. Further information on the correlation among test segments and on the reliability of the test as a whole will be obtained from a related Committee project currently being carried out at the State University of Iowa by K. W. Spence and C. E. Buxton.

of proven ability and were motivated to do well in the test. The mean for 13 candidates who were dropped for poor aptitude or physical disabilities was 5.53 minutes, four of them making scores above 6.00 minutes. Any score above six minutes was considered to be disqualifying for students of this group if combined with poor scores in two or more of the other psychomotor and mental tests.

SUMMARY

A revised model of the Mashburn apparatus was constructed differing from the original in that it was made with parts purchased from commercial manufacturers thereby standardizing the structural and operational features of the equipment. In this model the buzzer, the transformer, the stimulus and distraction lights and a 26 point stepping relay were included in a metal unit supported on an upright frame. All units were wired to a central terminal strip permitting the removal of any part for replacement or repair.

Preliminary data were obtained on both the original and revised models of the equipment. Test scores were compared with criteria of flight success, viz., pass-fail performance during flight training for the naval cadets tested, and time to solo and time for certification for the civilian trainees tested. In all groups tested the differences between the mean scores for successful and unsuccessful pilots were greater than those expected on the basis of chance fluctuation in random sampling. Intercorrelations among the three independent series of 13 settings were between .70 and .77, suggesting that the test possesses reliability adequate for further research on the use of the instrument in the prediction of flight achievement.

APPENDIX A

ELECTRICAL INTERCONNECTIONS

Wiring Plan No. 1
Wiring Plan No. 2

STIMULUS PATTERNS OF RED LIGHTS

APPENDIX A

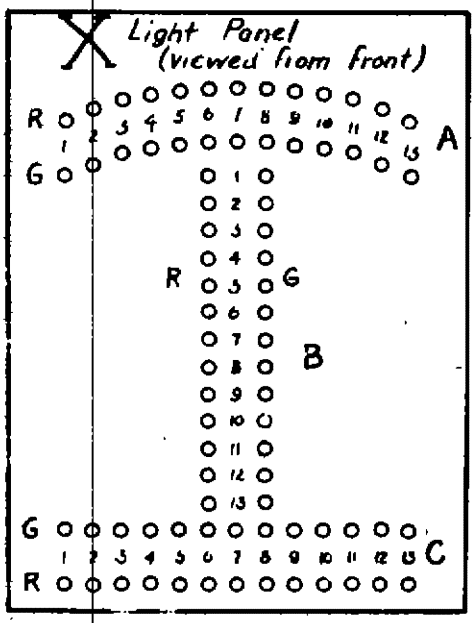
ELECTRICAL INTERCONNECTIONS

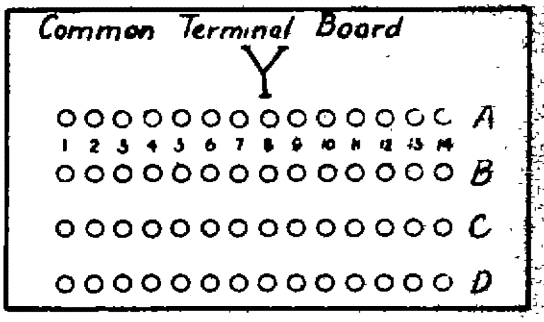
Wiring Plan No. 1
Wiring Plan No. 2

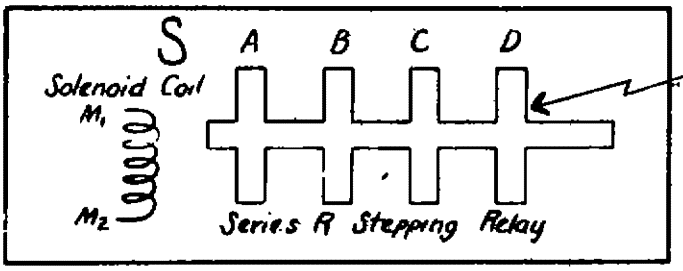
STIMULUS PATTERNS OF RED LIGHTS

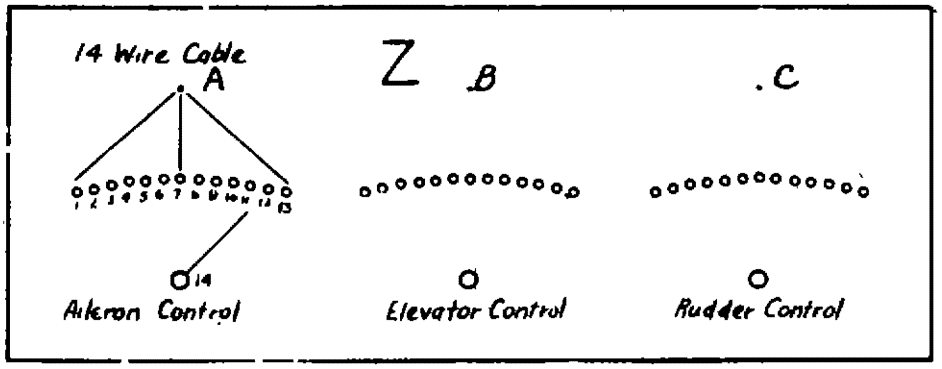
ELECTRICAL INTERCONNECTIONS

Wiring Plan No. 1

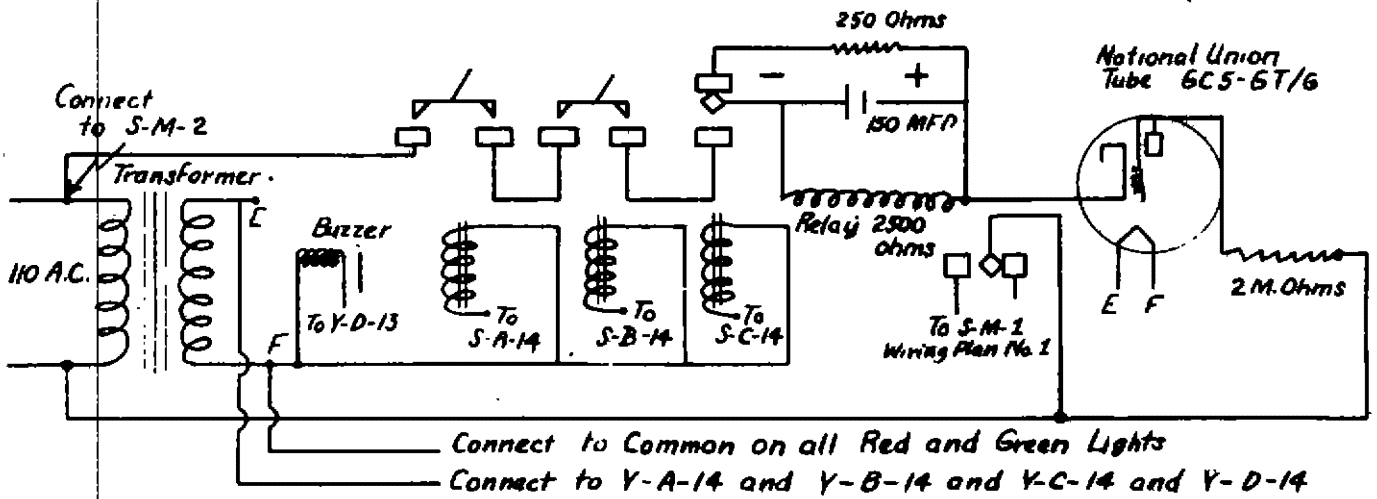








Relay Shelf - Wiring Plan No. 2



APPENDIX A-6

SWITCHING PATTERNS OF RED LIGHTS

(Viewed from Front of Apparatus)

Section A

Number	A.	B.	C.	Number	A.	B.	C.	
1	13	7	10	7	8	9	5	
2	7	3	4	8	3	12	1	
3	1	10	8	9	5	6	7	These correspond to the numbers assigned to the lights in Part X of Wiring Plan No.1 of Appendix A-1.
4	6	4	13	10	4	1	3	
5	2	8	9	11	11	11	12	
6	10	13	11	12	12	5	6	
			Buzzer (13)	2		2		

Section B INTERCONNECTIONS BETWEEN Y AND Z

(See Electrical Interconnections: Appendix A-1)

Z-A-1 to Y-A-1, Z-A-2 to Y-A-2, Z-A-3 to Y-A-3, etc., common lead to Y-A-14
Z-B-1 to Y-B-1, Z-B-2 to Y-B-2, Z-B-3 to Y-B-3, etc., common lead to Y-B-14
Z-C-1 to Y-C-1, Z-C-2 to Y-C-2, Z-C-3 to Y-C-3, etc., common lead to Y-C-14

INTERCONNECTIONS BETWEEN X AND Y

X-A-R13 and X-B-R7 and X-C-R10 to Y-D-1
X-A-R7 and X-B-R3 and X-C-R4 to Y-D-2
X-A-R1 and X-B-R10 and X-C-R8 to Y-D-3
X-A-R6 and X-B-R4 and X-C-R13 to Y-D-4
X-A-R2 and X-B-R8 and X-C-R9 to Y-D-5
X-A-R10 and X-B-R13 and X-C-R11 to Y-D-6
X-A-R8 and X-B-R9 and X-C-R5 to Y-D-7
X-A-R3 and X-B-R12 and X-C-R1 to Y-D-8
X-A-R5 and X-B-R6 and X-C-R7 to Y-D-9
X-A-R4 and X-B-R1 and X-C-R3 to Y-D-10
X-A-R11 and X-B-R11 and X-C-R12 to Y-D-11
X-A-R12 and X-B-R5 and X-C-R6 to Y-D-12
X-A-R9 and X-B-R2 and X-C-R2 to Y-D-13

X-A-G-1 to Y-A-1, X-A-G-2 to Y-A-2, etc.
X-B-G-1 to Y-B-1, X-B-G-2 to Y-B-2, etc.

INTERCONNECTIONS BETWEEN S AND Y

Y-A-13 to S-A-1, Y-B-7 to S-B-1, Y-C-10 to S-C-1
Y-A-7 to S-A-2, Y-B-3 to S-B-2, Y-C-4 to S-C-2
Y-A-1 to S-A-3, Y-B-10 to S-B-3, Y-C-8 to S-C-3
Y-A-6 to S-A-4, Y-B-4 to S-B-4, Y-C-13 to S-C-4
Y-A-2 to S-A-5, Y-B-8 to S-B-5, Y-C-9 to S-C-5
Y-A-10 to S-A-6, Y-B-13 to S-B-6, Y-C-11 to S-C-6
Y-A-8 to S-A-7, Y-B-9 to S-B-7, Y-C-5 to S-C-7
Y-A-3 to S-A-8, Y-B-12 to S-B-8, Y-C-1 to S-C-8
Y-A-5 to S-A-9, Y-B-6 to S-B-9, Y-C-7 to S-C-9
Y-A-4 to S-A-10, Y-B-1 to S-B-10, Y-C-3 to S-C-10
Y-A-11 to S-A-11, Y-B-11 to S-B-11, Y-C-12 to S-C-11
Y-A-12 to S-A-12, Y-B-5 to S-B-12, Y-C-6 to S-C-12
Y-A-9 to S-A-13, Y-B-2 to S-B-13, Y-C-2 to S-C-13

Y-D-1 to S-D-1, Y-D-2, to S-D-2, Y-D-3 to S-D-3, etc.
Y-D-14 to S-D-14

APPENDIX B

DIRECTIONS FOR GIVING THE SERIAL REACTION TIME TEST

APPENDIX B

DIRECTIONS FOR GIVING THE SERIAL REACTION TIME TEST

In order to obtain the best results with the test, the following instructions and procedure should be adhered to very rigidly. The experimenter should either memorize the instructions or read each step from a 3 x 5 inch card held in the palm of the hand. This will make certain that each subject receives the same standard instructions.

(1) Seat the subject comfortably and have him adjust the seat so that he can easily reach the controls.

(2) Demonstrate on one pattern (the second after the buzzer from the preceding test) how the controls operate the green lights, as follows: "Take hold of the stick and move it from side to side. The side movement of the stick controls the top green lights. The fore and aft movements of the stick control the center green lights. The movement of the feet controls the bottom green lights. Your problem is to match the three red lights with the green ones."

(3) Pattern changes with demonstration. "You will notice that when all three lights are matched the pattern changes. Now you practice a few of these patterns. Keep your heels free from the floor board."

(4) Allow the subject to practice until the buzzer stops for the first time. Stop him by turning off the switch and give the following instructions: "You will have a series of forty of these settings to complete. You will be scored on the quickness with which you complete this series. Pay no attention to the buzzer which will sound at intervals, but continue the test as fast as you can until you are told to stop. Do you understand the instructions?"

(5) Turn on the switch. "Are you ready? Go!" "Now run through the series as fast as you can."

Notes on Timing: Start the stop watch when you give the signal "Go." Record the time at the end of the first, second, and third buzzer signals, and at the end of one setting beyond the third buzzer signal (after 13, 26, 39, and 40 settings, respectively). If the machine is then left in this position, it is ready for the next subject who will have one demonstration trial and eleven practice trials. A stop watch graduated in minutes and decimals of a minute is the most desirable type for the testing procedure.

APPENDIX C

LIST OF SPECIAL PARTS AND NAMES OF MANUFACTURERS

	Name and Address of Manufacturer	Name or Description of Part	Quantity per Unit	Catalog Number
1.	Potter & Brumfield Mfg. Co., Inc. Princeton, Indiana	6 volt, 60 cycle relay	2	[illegible]-1-SP[illegible]
		6 volt, 60 cycle relay	1	PLA-3-SPDF
		[illegible] volt, 60 cycle relay, with high resistance coil	1	M-[illegible]
2.	Guardian Electric Co. 1621-27 W. Walnut St. Chicago, Illinois	R type stepping relays, 26 contacts	[illegible]	[illegible]
		[illegible]	3	
3.	Howard [illegible] Jones 2300 [illegible] Avenue Chicago, Illinois	35 point male plugs	3	[illegible] 2350CF
		35 point female plugs	3	[illegible] 2350CF
		34 point [illegible] strips	3	[illegible]
4.	Par Metal Products Corporation [illegible] Street Long Island City, N. [illegible]	[illegible]	[illegible]	[illegible]
5	[illegible] Mfg. Co. 5[illegible] Street Chicago, [illegible]	[illegible]	[illegible]	[illegible]
6.	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]
8.	[illegible] Co. [illegible]	[illegible]	[illegible]	[illegible]