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16. Abstract

Sixteen instrument-rated pilots, eight of whom were very experienced professional aviators, flew Instrument Landing System approaches in a Cessna 172 under simulated instrument flight conditions while sober and while under the influence of 40, 80, and 120 mg% of blood ethyl alcohol. Each pilot flew four approaches to minimums on each of two occasions at each alcohol level.

The data collected during these approaches included continuous measurement of aircraft position with respect to localizer and glide path centerlines and airspeed. Note was made of procedural errors committed during the flights.

The subjects showed significant and progressive decremental effects of alcohol at all of the levels studied. The more experienced pilots maintained their ability to guide the aircraft better than did the less experienced subjects, particularly at high levels of blood alcohol. Both groups, however, demonstrated progressive increases in the number and seriousness of procedural errors with increasing levels of alcohol.

It is concluded that even 40 mg% of blood alcohol exerts decremental effects on performance which are incompatible with flight safety.

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THE EFFECTS OF ALCOHOL ON PILOT PERFORMANCE DURING INSTRUMENT FLIGHT

INTRODUCTION

This research was initiated by the Federal Aviation Administration after receipt of an unsolicited proposal from the Aviation Medicine Research Laboratory of The Ohio State University. Contract No. FA68AC-6089-2 was signed in June, 1968 for a study of the effects of graded doses of ethyl alcohol on the capability of experienced professional pilots to fly light aircraft by reference to instruments. The study was later extended to include the effects of alcohol on less experienced pilots.

This report is a formal description of the rationale of the study, the methods used and the results obtained, with a discussion of their significance. The data collected during the course of the study, some 27,395,000 computer words, and the first stage computer output, amounting to 12,120 statistical descriptors of 501 instrument approaches, are not included in the report; they are available for further study on request. The report includes the results of all statistical analyses performed on these data in summary form.

Portions of this research have already been presented at scientific meetings or in publications (1,2,3). The pertinent material summarized in the earlier reports is included here for the sake of completeness.

The report is constructed on conventional lines. Detailed descriptions of the performance measures used, and equations for them, are found in appendices. Another appendix summarizes all of the data, partitioned by experimental condition.

BACKGROUND

The role of alcohol as a contributing factor in general aviation accidents has received considerable attention during the past decade. An informal study in 1962 noted that during the three-year period 1957-60, 40-50% of accidents in which alcohol was known to be involved were fatal (4). Only about ten percent of accidents in which alcohol was not involved were fatal.

A subsequent study by Harper and Albers (5) suggested that measurable levels of blood alcohol were associated with approximately 35% of all fatal general aviation accidents during 1963. Their estimate was based on 56 positive alcohol findings in 158 fatal accidents in which toxicological analyses were done, out of 477 fatal aircraft crashes in that year. While the reliability of these data is open to some question because of the different techniques used in handling and analyzing the various specimens, other studies have also indicated that alcohol may be involved in up to 40% of fatal accidents in some regions of the country (6,7).

The National Transportation Safety Board has generally been rather conservative about ascribing the cause of accidents to alcohol. This drug has in the past been reported as the probable cause only when it has been known to be present and other probable cause factors have not been found. During recent months, however, the NTSB has reexamined this policy and has been listing alcohol as at least a contributing factor in fatal accidents when levels greater than 50 mg % are found (8). During 1967-69, the Board reported alcohol as a probable cause in 136 of 1942 fatal general aviation accidents (7%). Alcohol has been reported as the probable cause of slightly less than 1% of all accidents in aviation, though the data in non-fatal accidents are less accurate.

It is difficult to ascertain exactly where the truth lies in this area. Harper and Albers used 15 mg % (0.015%) as their lower limit of blood alcohol. The NTSB until recently has been reluctant to impugn alcohol as a cause factor if levels have been below 150 mg % (0.15%), a concentration at which a prima facie finding of intoxication may be made under the law in 46 states. Many states now define intoxication as being present at 100 mg %, however, and Utah uses 80 mg %, as do the United Kingdom and several European nations. The average blood alcohol reported by Harper and Albers was 147 mg %, a value close to the most liberal of the values defined by state laws in this country.

There is little question about the role of high levels of blood alcohol in either aircraft or motor vehicle accidents. A much more substantial question arises when lower blood alcohol levels are found. If it is assumed that there is some low level at which alcohol ceases to be a factor, what is the level? In particular, is alcohol a problem of any magnitude in aviation when it is present at levels below 80 mg %, the lowest value at which intoxication is presumed to be present by the laws of any western nation? This research was designed to provide at least partial answers to these questions.

Studies of man's performance under stress may be carried out either in the laboratory, where uncontrolled variables may be minimized, or in the field. The classic simulator study of Asknes (9) was the first to relate alcohol to flight skills. Whether data obtained in simulated environments are directly applicable to the real world is as yet an unanswered question. On the other hand, studies in actual flight must be constrained by considerations related to the safety both of the subjects and of others in the flight environment, so that "total simulation" of the stress situation is usually impossible even when the environment and vehicle are real.

A great many prospective and retrospective studies of the role of alcohol in automobile operation have been performed. An excellent review and summary of this literature is available (10). Much less has been done prospectively in aviation, though one laboratory study of the effects of alcohol and acceleration has been completed recently (11,12).

A review of the extensive literature on the metabolism of alcohol *in vivo* is beyond the scope of this report. It should be noted, however, that many of the studies to date have evaluated performance after administration either of a fixed dose of alcohol per unit of body weight, or after bringing subjects to a desired level of blood alcohol; in either case, performance has been studied while alcohol levels were declining at whatever rates were characteristic of the subjects being studied. In the research reported here, an attempt was made to circumvent this problem by providing maintenance doses of alcohol at intervals while the subjects were under study.

MATERIALS AND METHODS

Subjects:

This study was carried out in two phases. Phase I utilized as subjects eight experienced professional pilots; pertinent data regarding these volunteers are summarized in table I. Phase II was, insofar as possible, a replication of phase I, utilizing relatively less experienced but still instrument-rated pilots, whose data are also summarized in table I. Since systematic differences were found between the two groups, their data are presented separately throughout the report.

All of the subjects were social drinkers, though the extent of their normal alcohol intake varied considerably. All subjects were known to the investigators; none was believed to have emotional problems related to alcohol or any degree of psychophysiological dependence on this or other drugs.

Aircraft:

The airplane used in the experiments was a 1959 Cessna Model 172, extensively modified as a research vehicle and carrying an experimental category airworthiness certificate. The airplane's flight instrumentation included gyroscopic instruments powered by an engine-driven vacuum pump, a navigation receiver and glide slope receiver, a marker beacon receiver and audio isolation amplifier, and two communications transceivers. The aircraft equipment is listed in appendix 1.

Instrumentation:

Research instrumentation included temperature and humidity compensated rotary potentiometers attached to the throttle and control cables, a venturi system for airspeed assessment and pickups connected to the pilot's cross-pointer instrument. These sensors were connected to an interface unit; their outputs were amplified and connected to a 7-channel FM instrumentation recorder. The pilot's electrocardiogram was also recorded, together with communications, the audio output from the marker beacon, and audio event signals initiated by the safety pilot. Details of the instrumentation are also given in appendix 1. Table II summarizes the data available on the FM analog tapes.

Table I: Subject Data

Phase	#	FAA Rating	Flight Total Time Hours	Instrument Flight Time	Remarks
I	1	Commercial & Instrument	6,500	350	Pilot Examiner
	2	ATR	13,000	1,400	Pilot Examiner
	3	ATR	17,000	2,000	Chief Pilot Photo Service
	4	ATR	6,000	750	Pilot Examiner
	5	Commercial & Instrument	4,000	850	USAF Instructor Pilot
	6	ATR	12,000	1,350	
	7	ATR	12,000	1,400	
	8	Commercial & Instrument	7,000	900	USA Standardization Pilot
II	1	Commercial & Instrument	1,000	60	
	2	Private & Instrument	230	50	
	3	Commercial & Instrument	605	45	Flight Instructor
	4	Private & Instrument	620	190	
	5	Commercial & Instrument	491	35	
	6	Commercial & Instrument	939	94	
	7	Private & Instrument	400	89	
	8	Private & Instrument	340	85	

TABLE II: DATA AVAILABLE ON TAPE

1. Position with respect to localizer course
2. Position with respect to glide path
3. Air speed, indicated
4. Throttle position
5. Elevator position
6. Aileron position
7. Rudder position
8. Electrocardiogram (subject)
9. Radio communications
10. Marker beacon audio output
11. Event marks (observer)

Environment:

All flights were conducted in the Columbus, Ohio, terminal area under radar observation by the Columbus air traffic control facility. Two ILS installations at Port Columbus International Airport were used for approaches. Appendix 2 reproduces approach plates for these two installations and diagrams of their geometry. Since aircrew members are not allowed to fly under the influence of alcohol, an exemption was obtained to permit the conduct of the experiment; this is also reproduced in appendix 2. A special aircraft call sign was used during data collection flights; ATC personnel were briefed in advance regarding the study, though they were not aware of the alcohol level on any individual flight. All flights were conducted at night under normal traffic control procedures.

Experimental Design:

Each phase of the experiment was a single-blind replicate study utilizing a complete randomized block design. The protocols are shown in appendix 3. Two flights were omitted in the second half of phase I because two pilots were unable to tolerate the highest level of blood alcohol. No flights were lost in phase II.

Each pilot (with the two exceptions noted above) flew on two nights at each of four levels of blood alcohol: 0, 40, 80 and 120 mg %. During each flight, four approaches to ILS minimum altitude (200' above field elevation) were completed. A minimum of 48 hours separated successive experimental flights to eliminate carryover effects. Prior to the start of data collection, each subject was allowed to fly the research aircraft until he was satisfied with his own performance. The experienced pilots used in phase I required an average of less than two hours to reach this self-imposed level of familiarity; the inexperienced pilots required about three hours of familiarization.

Initial Evaluation:

Prior to beginning the study, each subject was evaluated in the laboratory to determine his metabolic degradation constant for alcohol and to observe his behavior under the combined influence of 120 mg % blood alcohol and mild hypoxia (produced by exposure to a simulated altitude of 5,000' in an altitude chamber). The former study was done in order to determine the size and frequency of maintenance doses of alcohol necessary to maintain an essentially constant level of blood alcohol throughout the 2-2½ hour experimental flights; the latter study was performed as a safety precaution.

During the first quarter of phase I, alcohol was administered as a 50% solution of 80 proof (40% ethanol) Vodka in tomato juice. Thereafter, at the request of the subjects, orange juice was used in place of tomato juice. These beverages were thus 20% absolute alcohol solutions, a concentration previously found to promote optimal absorption of alcohol.

Metabolic decay constants were obtained by least squares regression analysis of data obtained at ten-minute intervals over a 2-hour period following administration of a priming dose calculated to produce a maximum blood concentration of 80 mg % alcohol. The primary doses were estimated by the following formula:

$$W \times 3 \text{ ml/lb} \times \frac{x \text{ mg } \%}{120 \text{ mg } \%} = y \text{ ml of 20\% alcohol solution,}$$

in which W = the body weight of the subject in pounds.

As a check on the accuracy of the calculated rates, each subject returned to the laboratory for the 120 mg % study at altitude. Although this study was originally designed to detect individuals who might become unruly at high levels of alcohol, it also served to eliminate several candidates who became ill at this dose of alcohol.

Alcohol Analyses:

All blood alcohol levels were estimated by alcohol analysis of expired air. A model 900 Breathalyzer ® (Stephenson Corporation, Red Bank, New Jersey) was used to obtain these analyses. The accuracy of the expired air analyses was evaluated by studies on venous blood drawn concurrently and examined in two forensic toxicology laboratories using two different analytic techniques. The correlation between breath analyses and blood samples analyzed by steam distillation and colorimetric techniques was +0.962; the correlation between breath analyses and blood analyzed by gas chromatography was +0.936. Regression analyses yielded linear data for metabolic decay (r =-.90 to-.98) with slopes which varied from 11 to 22 mg % of blood alcohol per hour. Appendix 4 provides dosage and decay data for each subject.

Flight Protocol:

A standard protocol was used for all data collection flights. On the day of a flight the subject ate his normal breakfast and went about his usual activities during the day. He ingested only soup and other rapidly-digested liquids for lunch. At least 3 hours after lunch and 2½ hours prior to takeoff time, the subject reported to the field laboratory. Under supervision of a physician or technician, the subject drank a previously prepared alcohol mixture at a rate approximating 5 ml. of mixture (thus 1 ml of absolute alcohol) per minute. The total volume of beverage provided the subject was divided into three equal parts. If 120 mg % was desired, all three contained 20% alcohol; if 80 or 40 mg % were desired, either the third, or the second and third, portions contained only enough alcohol to maintain the desired level, the total volume being maintained by distilled water.

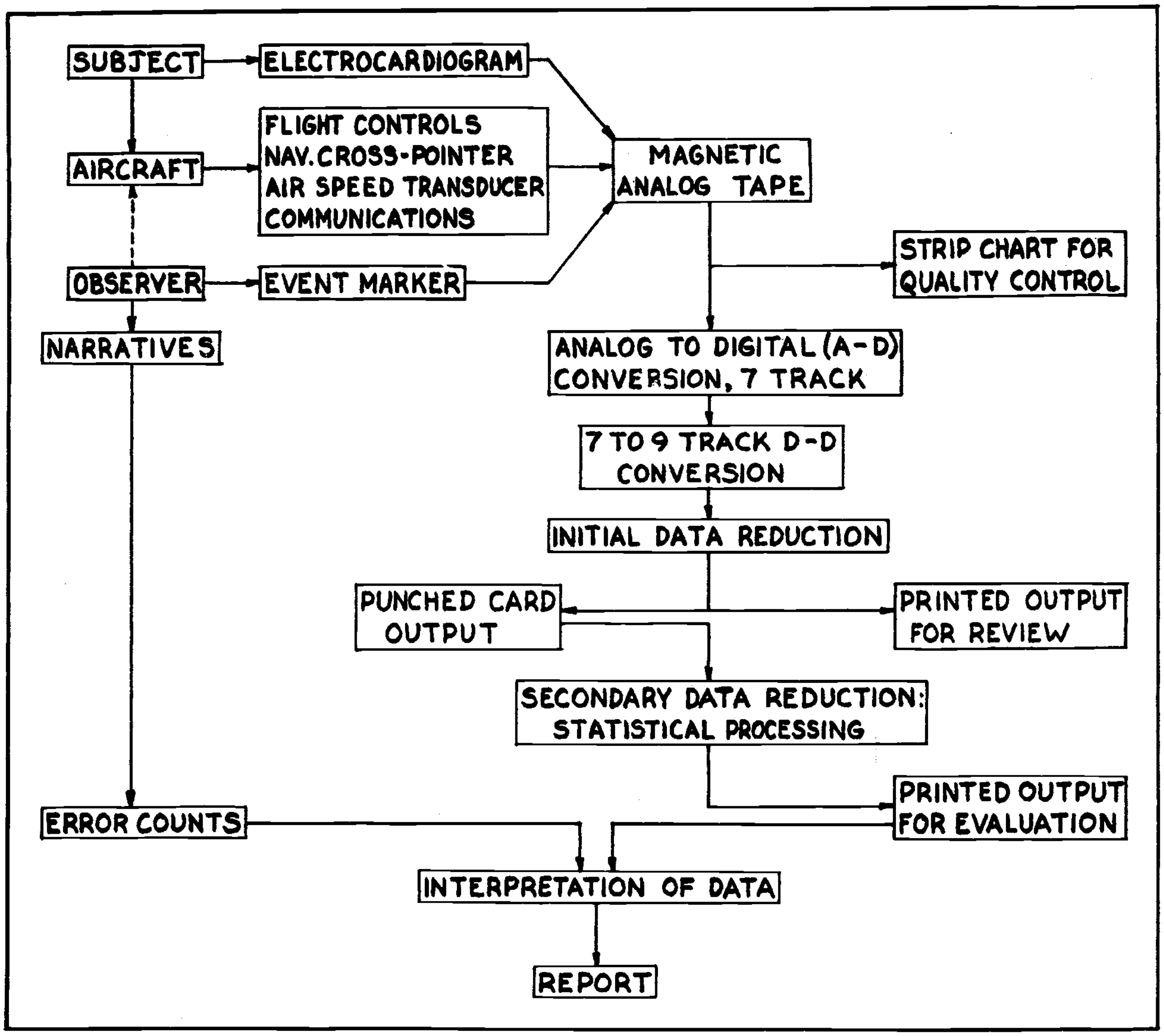
The first portion of the beverage contained some alcohol even on days when 0 mg % was desired, in a largely successful effort to confuse the subjects. The amount of alcohol on control days was small enough to allow its complete metabolism prior to flight.

Five minutes after finishing his priming dose, the subject rinsed his mouth thoroughly with water, then provided an expired air sample to confirm that the desired alcohol level had been reached. He then went to the aircraft. Previously affixed chest electrodes were connected to the instrumentation unit. (The airplane and instrumentation pre-flight inspections had been conducted in advance by the safety pilot and the technical observer). The Breathalyzer was placed in the airplane, ready for later use. Thereafter, the subject performed all of the duties of pilot-in-command, with one exception: the safety pilot responded to radio communications regarding other traffic in proximity to the experimental aircraft, since the subject was flying entirely by reference to instruments.

Takeoff time was normally scheduled for 40 minutes after sunset. The subject started the engine, taxiied, operated all radios, conducted the engine run-up, and took off. After take off, he donned an instrument hood, and then called Columbus approach control to request radar vectors to an ILS approach and full-stop landing. Approximately 2½ miles prior to outer marker passage, the tape recorder was activated by the technical observer, acting on instructions from the safety pilot who occupied the right front seat. Upon passing the outer marker, the safety pilot activated his event marker. A second event mark was placed on the tape upon passing the middle marker at minimum altitude. The subject then removed the hood and landed the aircraft. The tape recorder was turned off.

The subject taxiied back to the departure end of the runway and parked the aircraft. A second expired air sample was taken and analyzed, to allow the technical observer to calculate the volume and frequency of successive maintenance doses, which were administered as required during

FIGURE 1



SCHEMATIC OF DATA ACQUISITION, REDUCTION, EVALUATION AND REPORTING - RF 2626 cruising flight. The subject then received departure instructions, took off, and after donning his hood requested vectors for three more ILS approaches. The entire sequence was repeated except that the second and third approaches were terminated by missed approach procedures; the subject landed after the fourth approach, when a final breath alcohol determination was made. He then took off and returned to the Ohio State University airport under visual flight conditions, landed, parked and conducted the prescribed shut-down procedures. He was then driven to his home by the technical observer. This was done regardless of the alcohol level to maintain insofar as possible the "blind" conditions of the experiment.

Processing of Data:

The data tapes were reproduced on a strip-chart recorder the following morning to insure that all aircraft equipment was operating correctly. Processing of the tapes thereafter is described below. Since the taped data were not subject to observer bias, they are referred to hereafter as the "objective" data. Subjective data were also collected by the safety pilot during each flight; a narrative description of the flight was either dictated or transcribed within 12 hours of its termination. To minimize observer bias, the subjective observations were binary wherever possible. Note was made of all procedural errors committed by the subject, as well as of his affective responses to the alcohol and any unusual features of the flight. A copy of the strip-chart readout of one approach is shown in appendix 5, together with a representative narrative summary prepared by the safety pilot.

The objective (tape) data were processed according to the scheme noted in figure 1. The tapes were converted to digital format and processed by an IBM 360-75 computer. A variety of statistical descriptors was derived for each approach; the annotated output from one such approach is shown in appendix 6. The statistics shown therein were also punched on IBM cards, which were then processed further by the computer, using analysis of variance to discern effects of the variables in the experiment. A summary of the results of these analyses is contained in the body of the report; the analysis of variance matrices are shown in appendix 7.

The narrative summaries of the flights were reviewed by the safety pilot after each phase of the experiment was completed. At that time, he compiled a tabulation of errors of omission and commission for each flight, and classified these errors into four categories: errors involving the use or non-use of the carburetor heat control, and other errors, classified in one of three mutually exclusive categories.

1. MINOR ERRORS: Errors which do not affect the safety of the flight materially, but which are mistakes which a student pilot would not be expected to make upon reaching the degree of competence required for

solo flight. Examples include leaving lights or radios on when shutting down the aircraft, or failing to turn up the radio volume with resultant inability to establish two-way contact.

2. MAJOR ERRORS: Errors which can result in a hazard to flight safety or to the airplane if continued. These errors do not require immediate intervention by the safety pilot, but they may shorten engine life or degrade aircraft performance. No pilot would knowingly commit such errors. Examples include taking off with full flaps, flying without lights, taking off with carburetor heat on, turning the wrong way in response to instructions from ATC, attempting to fly an approach while tuned to the wrong ILS frequency.

3. CATASTROPHIC ERRORS: These errors require immediate intervention by the safety pilot to prevent an imminent accident or damage to the aircraft. In this experiment, the most common error of this type was an error during landing in which the safety pilot was obliged to take control to avoid striking the ground. Other examples included loss of control in flight, or turns toward oncoming traffic of which the subject had just been warned. Assessment of catastrophic errors did require a judgment by the safety pilot as to the quality of the subject's performance.

These errors were analyzed by chi-square analysis assuming that if the independent variable (alcohol) had no effect they would have occurred randomly across experimental conditions.

Evaluation of Performance

A variety of statistical descriptors of pilot performance was made available by the computer program used in this study. Each of the descriptors is defined rigorously in appendix 8. The descriptors discussed in the remainder of the report are briefly described here for the convenience of the reader. They are of three types.

1. MEASURES OF VARIABILITY: The measure of variability in trackin is the standard deviation of position or air speed, symbolized by the prefix (S).

2. MEASURES OF ERROR: The measure of error in tracking is the deviation in either direction from commanded position or air speed; its symbol in this report is (D).

3. TREND MEASURES: Measures of average rate of drift away from, c average rate of correction toward, commanded position are denoted by (AD), the average rate of drift, or (AC), the average rate of correction. The synthesis of these is the average rate of movement over a given time peri (AM), which is positive if the trend is in favor of drift away from commanded position, and negative if the trend is in favor of correction toward commanded position during a given time period.

All descriptor codes used in this report begin with one of the above symbols: S, D, AD, AC or AM, or with (HR) when heart rates are under consideration.

The tracking function being described is one of three; its symbol follows the descriptors above.

1. All localizer tracking has the symbol (L). The commanded or ideal position is attained when the localizer cross-pointer needle is centered, indicating that the airplane is on the localizer centerline. The angular width of the localizer course is $2\frac{1}{2}^{\circ}$ from center to full-scale needle deflection in either direction.

2. Glide path tracking has the symbol (G). The commanded position is attained when the glide path needle is centered, indicating that the airplane is precisely on the command glide path. The vertical width of the glide path is $\pm 0.7^{\circ}$ for a full-scale needle deflection.

3. Air speed tracking has the symbol (S). The command air speed was 90 mph during phase I of this study; during phase II it was raised to 100 mph to minimize interference with other traffic.

DS thus connotes deviation from command air speed; ADL connotes average rate of drift away from localizer centerline.

The above descriptors may be modified by a suffix if the data being presented do not refer to an entire approach. If no suffix is found, as in the two examples just cited, the data cover all of the approach. The suffixes are explained below.

The suffix (T) refers to the last, or terminal, 60 seconds of the approach. The suffix (2) refers to the immediately preceding 60 seconds. The suffix (3) refers to the next preceding 60 second period; (4) denotes data collected during the next preceding minute. The suffix (0) refers to data collected during the first four seconds of the approach, while crossing the outer marker; similarly, (M) refers to the last four seconds of the approach, while crossing the middle marker.

The sequence of data: DL0, DL, DL4, DL3, DL2, DLT, DLM, thus refers to the airplane's average deviations (in either direction) from localizer centerline when over the outer marker, during the entire approach, during each of the four last minutes of the approach in order, and as it passes the middle marker.

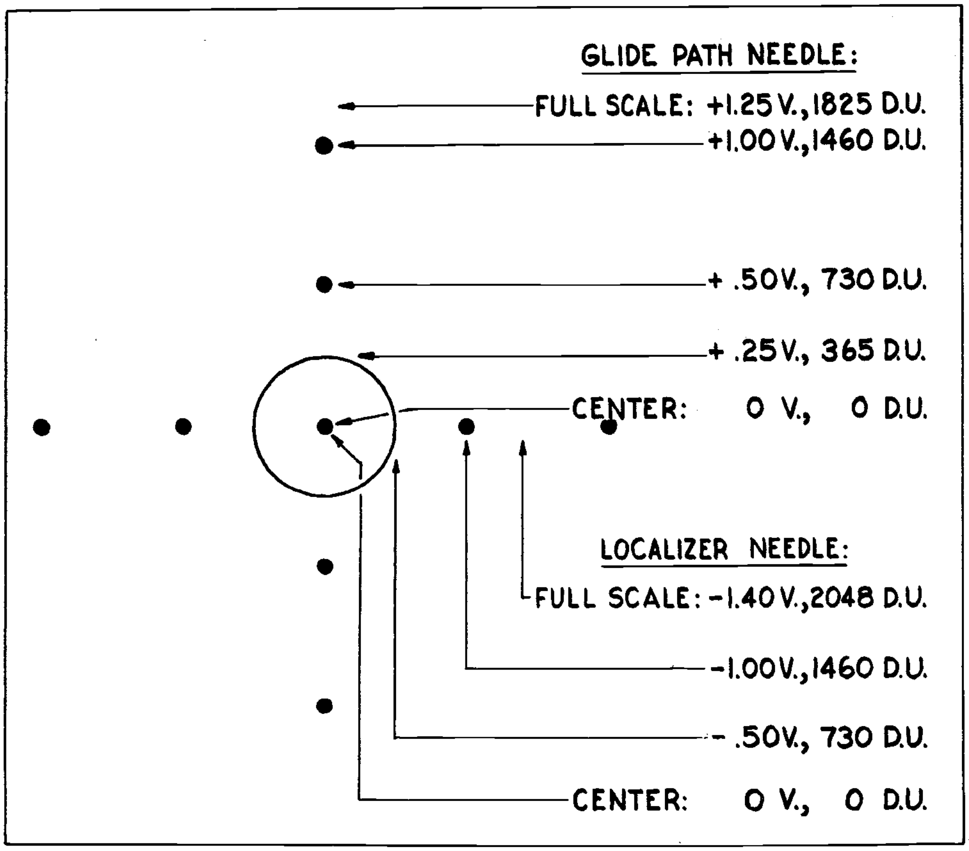
To simplify the reader's task, a brief list of the common performance descriptors and a summary of the notation used in figures is incorporated as a fold-out inside the back cover. This can be opened outward and left extended for reference while reading the text.

Airspeed data in this report are in statute miles per hour. Localizer and glide path data are in digital units representative of needle deflections. Different amplification ratios were used for localizer and glide path voltages in an effort to obtain maximum sensitivity; figure 2 shows the digital values associated with cross-pointer needle deflections in each axis. It will be noted that the values associated with localizer deflections are twice those for equal glide path needle deflections.

Procedural errors, as previously noted, are classified in three categories according to seriousness. Carburetor heat errors, for reasons noted below, are discussed separately.

Subjective comments regarding performance are discussed separately and have not been reduced to scalar quantities or otherwise modified for statistical analysis.

FIGURE 2



ILS CROSS-POINTER INSTRUMENT: SCHEMATIC
SHOWING AMPLIFIED VOLTAGES AND DIGITAL EQUIVALENTS USED IN THIS STUDY

RESULTS

This chapter is organized in two sections. The first presents the results of computer analyses of the positional and air speed data recorded continuously during all approaches. These data represent the pilot's ability to direct his aircraft toward a desired landing spot on the runway at a given air speed. The second section describes the secondary elements of the flying task in terms of the procedural errors observed during the flights. Prior to these two sections, however, an introduction describes certain preliminary analyses which were performed in an effort to ascertain whether the data from phases I and II could fairly be combined.

Preliminary results:

The two phases of this experiment were performed as independent experiments, utilizing samples of 8 subjects presumably drawn from two different populations of instrument-rated aviators.

The first step in analyzing the data was to determine whether this premise was correct. The mean data from all control (0 mgm %) flights by the inexperienced group studied during phase II, a total of 64 approaches, were compared with the comparable data provided by the more experienced pilots during phase I. Table III and figure 3 summarize the data.

It was found that the inexperienced pilots, when sober, had average localizer and airspeed deviations slightly smaller than those of the experienced pilots. Their glide path deviations were slightly greater, but this difference disappeared during the terminal minute of the approaches. The inexperienced pilots showed greater tracking variability than the more experienced men, and their average drift and correction rates were higher. They were somewhat closer to localizer and thus runway centerline as they crossed the middle marker, but they were substantially further from command position on the glide path at the middle marker. The inexperienced group also committed more major errors than the experienced group during 0 level flights.

A second preliminary study compared the first control flight of the two phases with the second, in order to ascertain whether learning effects may have been present. No systematic differences were seen in the data provided by the experienced pilots. Some effects were observed, on the other hand, in the inexperienced pilot data. These are discussed later in the report.

Virtually all of the observed differences between the two groups were in the expected direction. The presence of these differences suggested that the data from the two phases should be analyzed separately, rather than in one body, in order to allow observation of differences in modes of

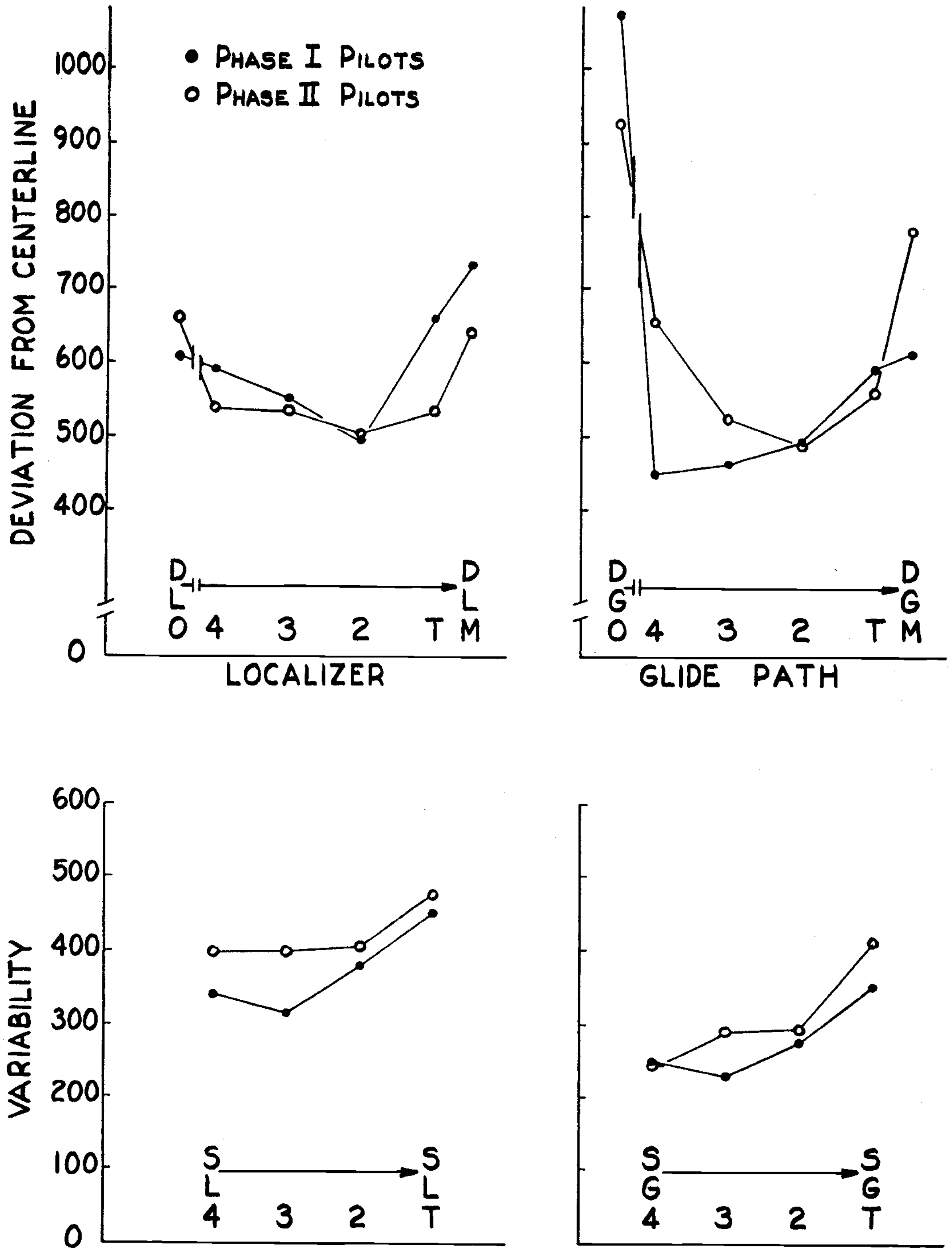
TABLE III: COMPARISON OF SUBJECT GROUPS: CONTROL (NO ALCOHOL)

Variable	I	II	II/I	Variable	I	II	II/I
SL	505	603	1.19	SG	459	532	1.16
SLT	445	474	1.07	SGT	350	408	1.17
DLO	607	661	1.09	DGO	1072	925	.86
DL	566	546	.96	DG	536	581	1.08
DLT	652	534	.82	DGT	587	567	.97
DLM	732	637	.87	DGM	609	778	1.28
ADL	21.8	26.9	1.23	ADG	59.1	67.5	1.14
ADLT	13.3	17.2	1.29	ADGT	61.5	68.6	1.12
ACL	-22.0	-26.4	1.20	ACG	-59.4	-65.2	1.10
ACLT	-13.0	-16.4	1.26	ACGT	-65.3	-73.7	1.13
AMLT	.15	.39	2.60	AMGT	-1.92	-2.53	1.32
ACL/ADL	1.01	.98	.97	ACG/ADG	1.01	.97	.96
ACLT/ADLT	.98	.95	.97	ACGT/ADGT	1.06	1.07	1.01

Variable	I	II	II/I
SS	9.7	9.8	1.01
SST	1.7	2.0	1.18
DSO	4.4	3.8	.86
DS	3.8	3.6	.95
DST	3.8	3.7	.97
DSM	3.6	3.5	.97

I: Phase I: Experienced Pilots
II: Phase II: Inexperienced Pilots

FIGURE 3



COMPARISON OF EXPERIENCED (PHASE I) WITH INEXPERIENCED (PHASE II) PILOTS DURING CONTROL FLIGHTS (NO ALCOHOL)

TABLE IV: ESTIMATED BLOOD ALCOHOL CONCENTRATIONS

(Number, Mean, Standard Deviation, Standard Error)

mg %

	Phase I		
	40	80	120
Before Flight	16	16	14
	39.43	80.00	117.43
	10.38	6.66	13.21
	2.59	1.67	3.53
After 1st Approach	16	16	14
	39.94	78.63	118.79
	6.06	5.20	3.56
	1.52	1.30	0.95
After 4th Approach	16	16	13
	43.13	80.25	121.31
	7.14	6.10	6.71
	1.78	1.53	1.86

	Phase II		
	40	80	120
Before Flight	16	16	16
	34.06	72.88	114.31
	6.32	7.67	10.49
	1.58	1.92	2.62
After 1st Approach	16	16	16
	33.56	76.63	112.06
	7.92	6.14	7.80
	1.98	1.54	1.95
After 4th Approach	16	16	16
	38.25	82.69	120.19
	4.67	3.14	7.47
	1.17	0.78	1.87

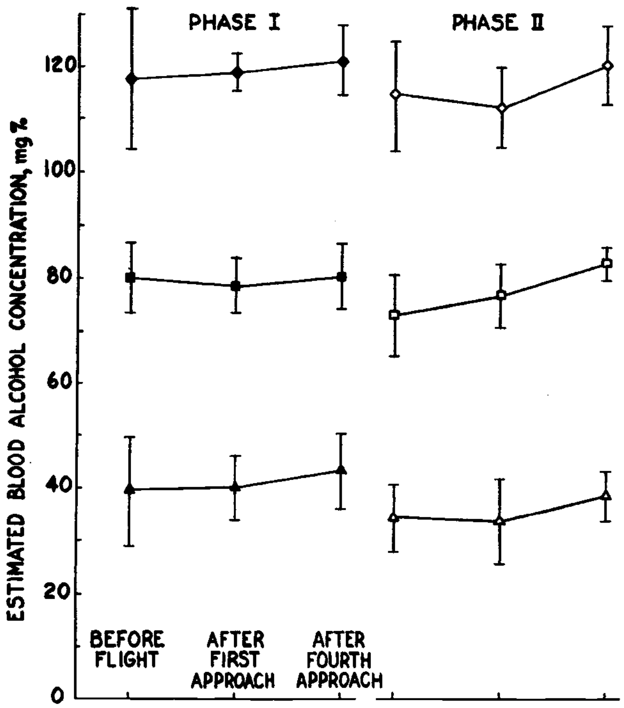
degradation under the influence of alcohol if such differences existed to a significant degree.

Figure 4 and table IV summarize the results of alcohol analyses during the data flights. Phase II alcohol levels were somewhat lower than the phase I data, though it should be recalled that the second and third values, taken during the data collection, are more important than the initial value, taken immediately after the initial dosing period.

Note, in figures 3 and 4, the symbols which are used in all figures in the report. Closed symbols signify data provided by the experienced pilots (phase I), while open symbols signify the inexperienced pilots (phase II). Alcohol levels are symbolized as follows: (O●) 0 mg % - control data; (△▲) 40 mg %; (□■) 80 mg %; (◇◆) 120 mg %.

Table V summarizes the results of analyses of variance performed on the dependent variables. It is obvious that there were significant interactions of subjects and treatments in nearly all of the variables. Primary treatment effects were also observed; the differences between the experienced and inexperienced pilots were considerable. They raised the possibility that the effects of alcohol were different in the two groups, a suspicion borne out in subsequent analyses.

FIGURE 4



RESULTS OF EXPIRED AIR ANALYSES
MEANS AND STD. DEVIATIONS

Table V

ANALYSES OF VARIANCE: F RATIOS

VARIABLE	Phase I				Phase II			
	Alcohol		Interaction		Alcohol		Interaction	
	F	P	F	P	F	P	F	P
SL	3.75	.05	2.65	.01	3.86	.05	2.05	.01
SLT	<1		2.30	.01	2.59		1	
SG	<1		3.60	.01	3.45	.05	2.04	.01
SGT	<1		3.18	.01	4.84	.05	2.18	.01
SS	3.26	.05	1.49		<1		<1	
SST	<1		10.85	.01	1.10		2.81	.01
DLO	5.62	.01	1.35		4.31	.01	1.56	
DL	2.05		3.73	.01	2.57		3.64	.01
DLT	<1		2.22	.01	1.80		3.18	.01
DLM	<1		1.76	.05	1.67		<1	
DGO	<1		3.00	.01	<1		2.27	.01
DG	1.41		3.78	.01	3.66	.05	2.10	.01
DGT	<1		2.84	.01	8.92	.01	1.36	
DGM	<1		2.32	.01	4.38	.01	<1	
DSO	<1		1.92	.05	<1		4.02	.01
DS	<1		4.63	.01	2.60		3.64	.01
DST	<1		6.07	.01	1.86		3.60	.01
DSM	<1		7.08	.01	1.85		3.17	.01
NDL	<1		4.53	.01	2.06		5.57	.01
NDLT	<1		3.34	.01	2.47		2.52	.01
NDG	1.02		3.86	.01	5.15	.01	1.49	
NDGT	2.33		1.44		1.42		1.30	
ADL	3.03		2.79	.01	1.77		2.30	.01
ADLT	<1		1.87	.05	1.66		1.04	
ACL	1.24		2.30	.01	2.57		2.35	.01
ACLT	<1		1.42		<1		<1	
ADG	1.24		3.45	.01	11.19	.01	1.20	
ADGT	1.43		2.55	.01	5.07	.01	2.56	.01
ACG	<1		3.03	.01	10.03	.01	1.79	.05
ACGT	<1		7.10	.01	4.54	.05	2.52	.01
AMLT	<1		1.71	.05	2.92	.05	<1	
AMGT	<1		2.97	.01	<1		1.00	

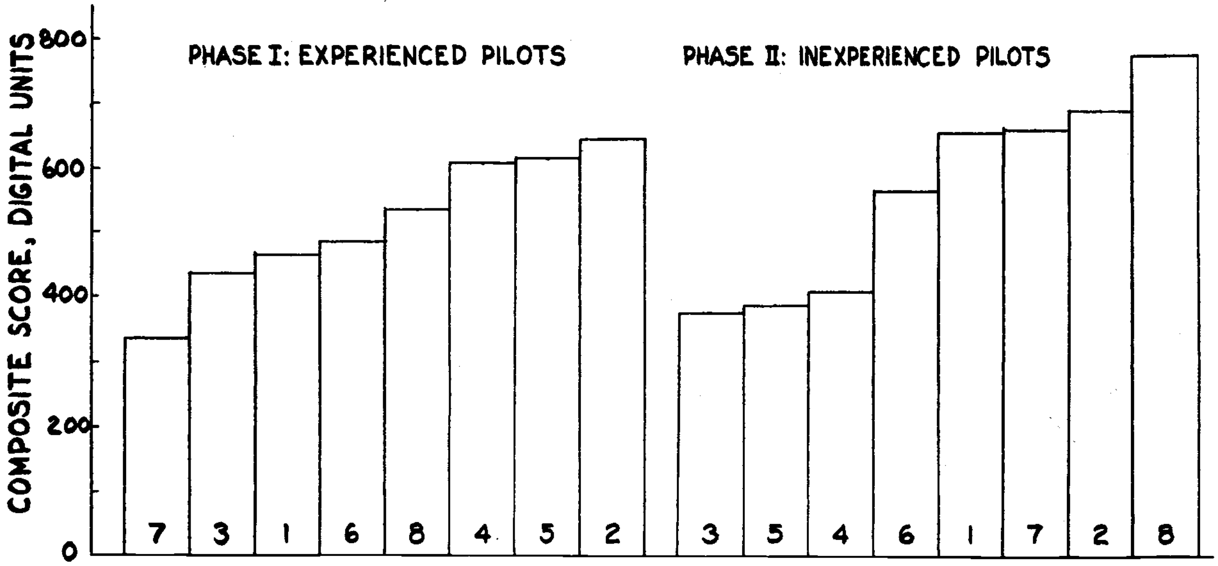
Objective Data: Effects of Alcohol

All significant interactions were examined graphically to determine whether differences in subject responses to alcohol were a matter of degree or whether they were qualitative in nature. As shown below in figure 6, there were marked differences in subject responses; in the body of the report, only those changes which were reasonably consistent are discussed in detail. One difference between the experienced and inexperienced pilots is immediately evident in table V: significant alcohol effects were observed only in lateral control in the experienced pilots. The inexperienced pilots, on the other hand, manifested significant alcohol effects in many performance descriptors of vertical control as well. This is discussed further below.

The subjects in each phase varied significantly among themselves in tracking skill. Figure 5 shows composite averages for four measures: variability on localizer and glide path (SL and SG) and deviations from localizer and glide path centerlines (DL and DG), during all control flights. It is obvious that there was much more within-group than between-group variability under these conditions. Similarly, there was considerable individual variability in response to alcohol; figure 6 shows relative increments or decrements in the composite score for all alcohol flights. This presentation is highly simplified, since a pilot who had a performance decrement only at 120 mg % might show very little average decrement when his 40 and 80 mg % data are included. The figure serves only to illustrate the variability in response and the fact that the inexperienced group, on the average, was degraded somewhat more by alcohol than the more experienced group.

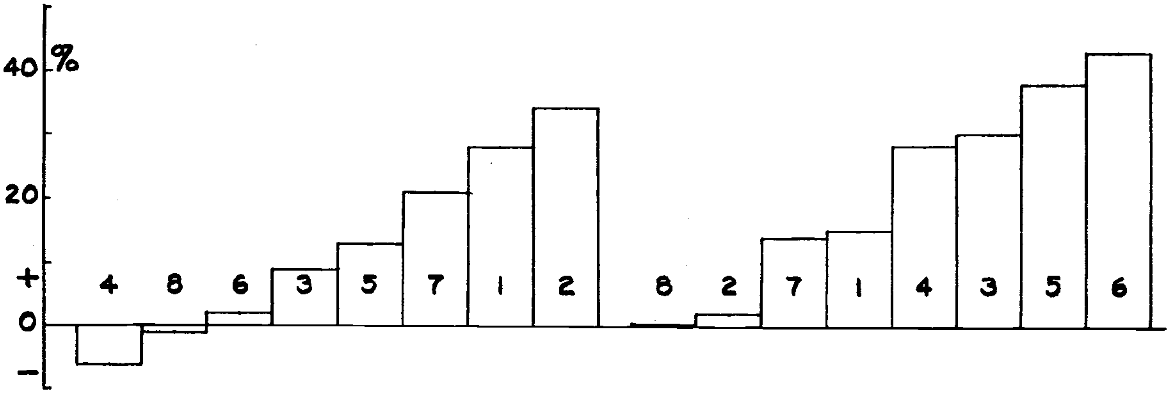
Looking at the composite scores by alcohol level, one obtains the results shown in figure 7, which suggests progressive decrements in performance with increasing alcohol levels, more pronounced in the inexperienced pilots. These composite scores were not tested for statistical significance in view of their synthetic nature, though it should be noted that they are composed of four functionally independent measures of tracking precision. As such, they provide a useful summary of the observed data.

FIGURE 5



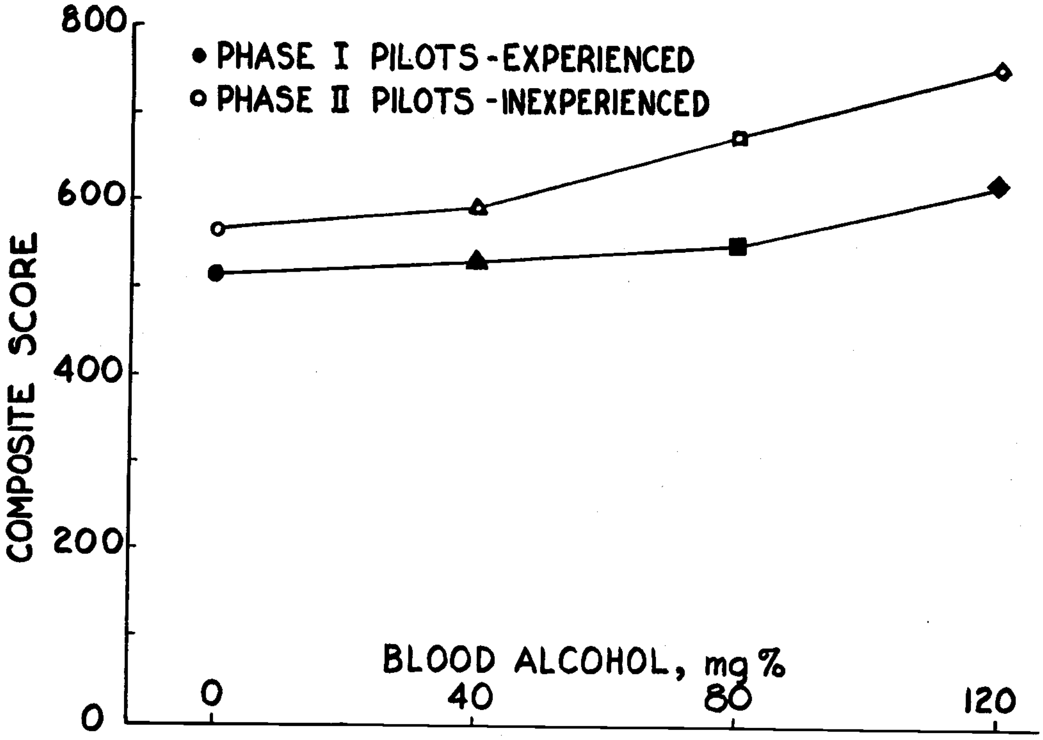
COMPOSITE PERFORMANCE SCORES DURING CONTROL FLIGHTS (NO ALCOHOL)

FIGURE 6

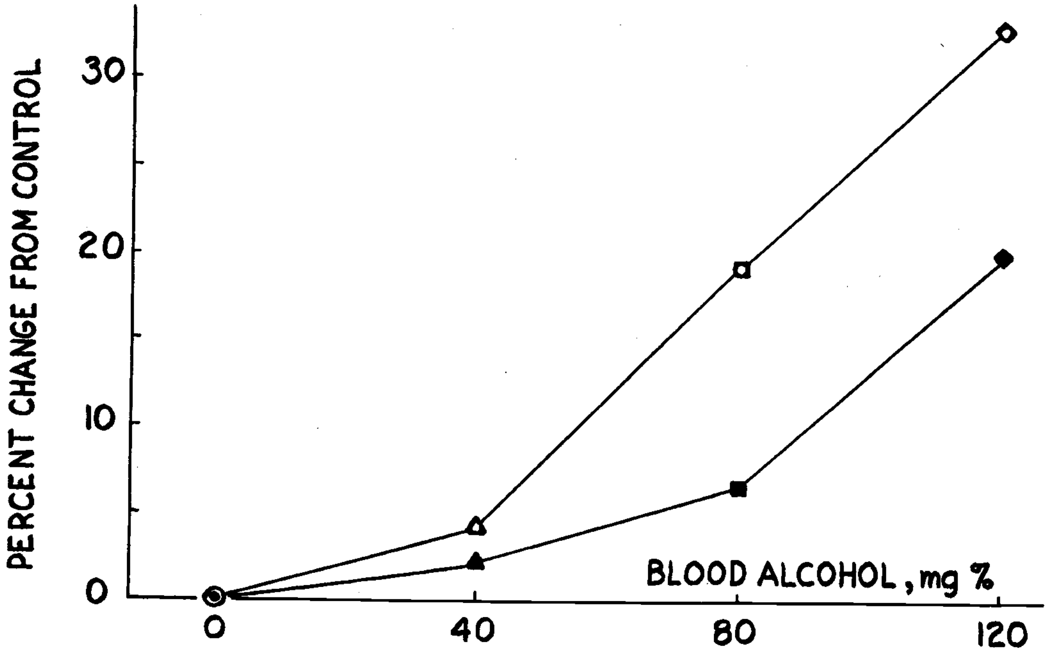


RELATIVE CHANGE IN COMPOSITE SCORES DURING ALL ALCOHOL FLIGHTS

FIGURE 7

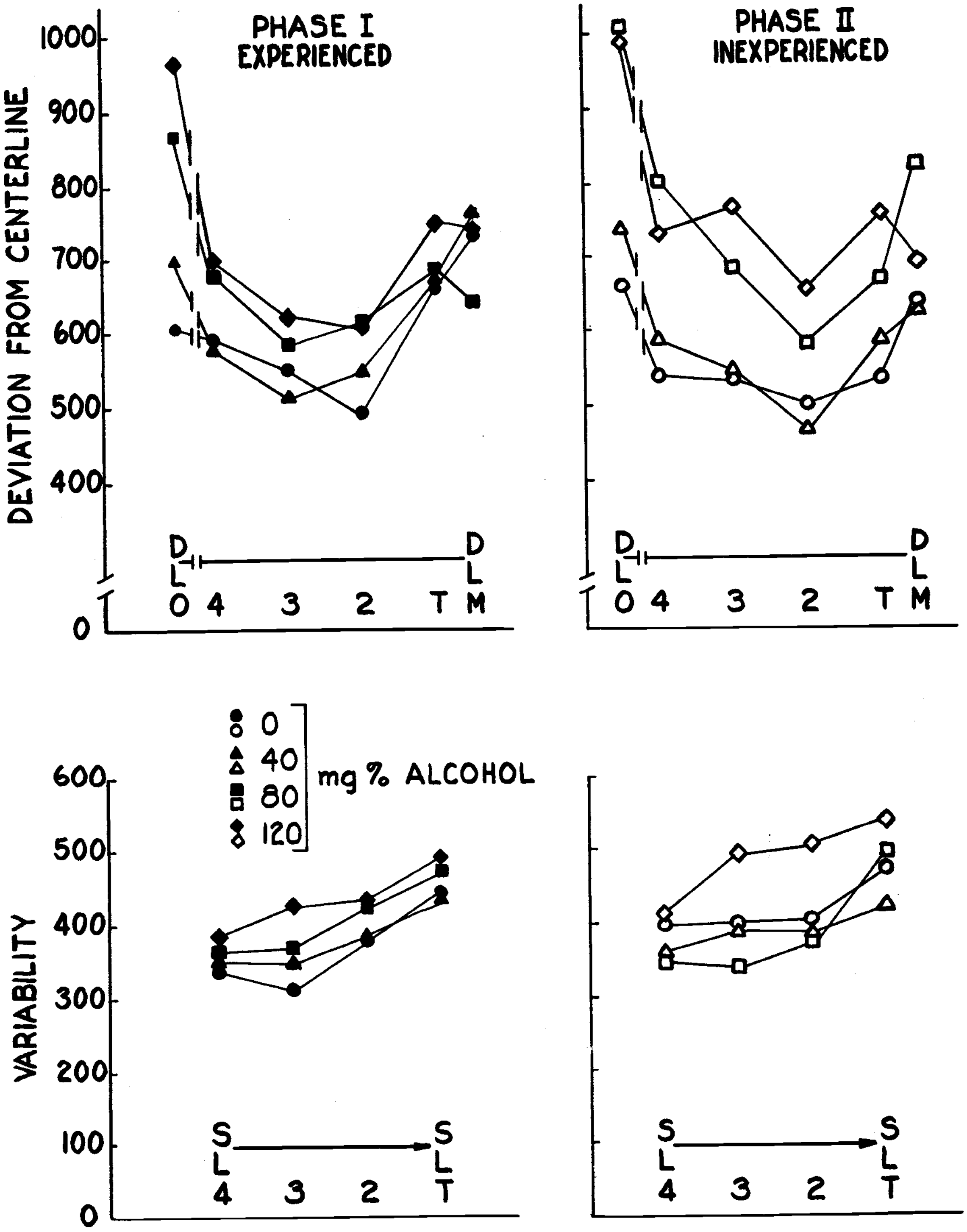


MEAN SCORES AT EACH ALCOHOL CONCENTRATION



RELATIVE DECREMENTS ASSOCIATED WITH ALCOHOL

FIGURE 8



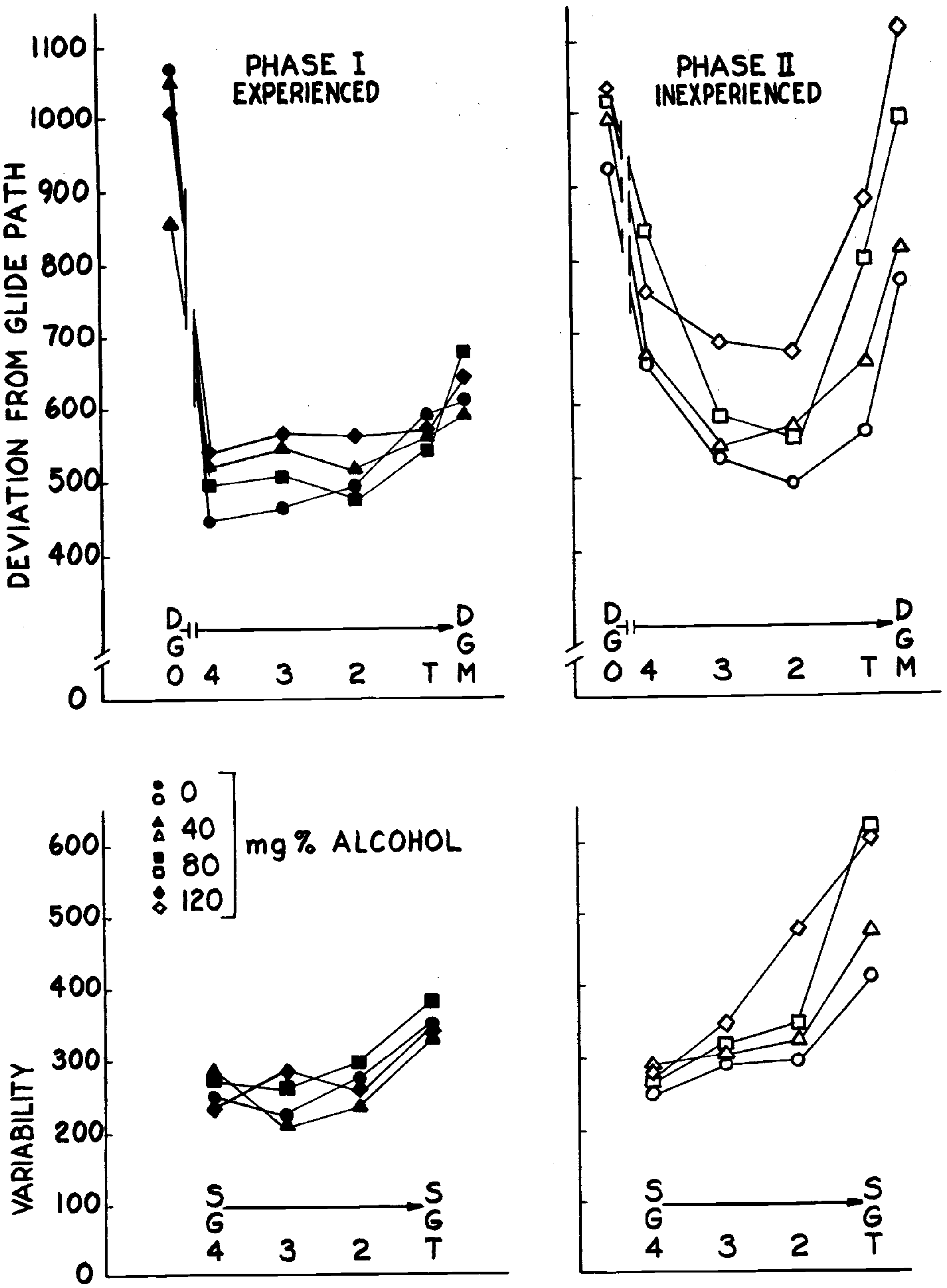
LOCALIZER TRACKING DURING CONTROL & ALCOHOL FLIGHTS

Table V indicates that in the experienced pilots, significant changes related to alcohol level were observed in only three dependent variables (plus a fourth, not listed but discussed below). One of these variables, SS (variability in air speed), appears to be spuriously significant for reasons noted on p. 29. Another variable, ADL (the average rate of drift with respect to localizer centerline) approached significance ($F = 3.03$; $F_{.05} = 3.07$).

A supplementary analysis indicated that deviations from localizer centerline exclusive of the terminal minute were significantly related to alcohol level ($p < .05$). The data shown in figure 8 show the localizer deviations of the experienced pilots at the outer marker and during each of the last four minutes of their approaches, terminating at the middle marker. The data suggest a progressive decrease in differences related to alcohol level, no systematic difference being apparent at the middle marker. The inexperienced pilots performed similarly with respect to localizer tracking, but decrements related to alcohol were larger, the differences at the middle marker being highly significant.

Variability in localizer tracking (SL) was significantly related to alcohol level in both groups of pilots. In both groups at all levels of alcohol, localizer variability increased during the last minute of the approach (SLT) but the means for the various levels did not differ significantly. Figure 8 also illustrates this trend, which was observed in virtually every pilot under all conditions.

FIGURE 9

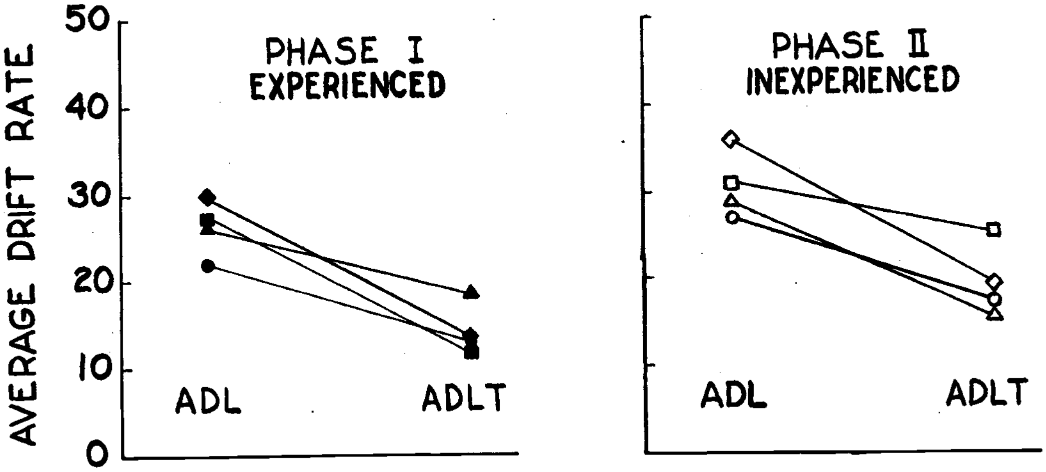


GLIDE PATH TRACKING DURING CONTROL AND ALCOHOL FLIGHTS

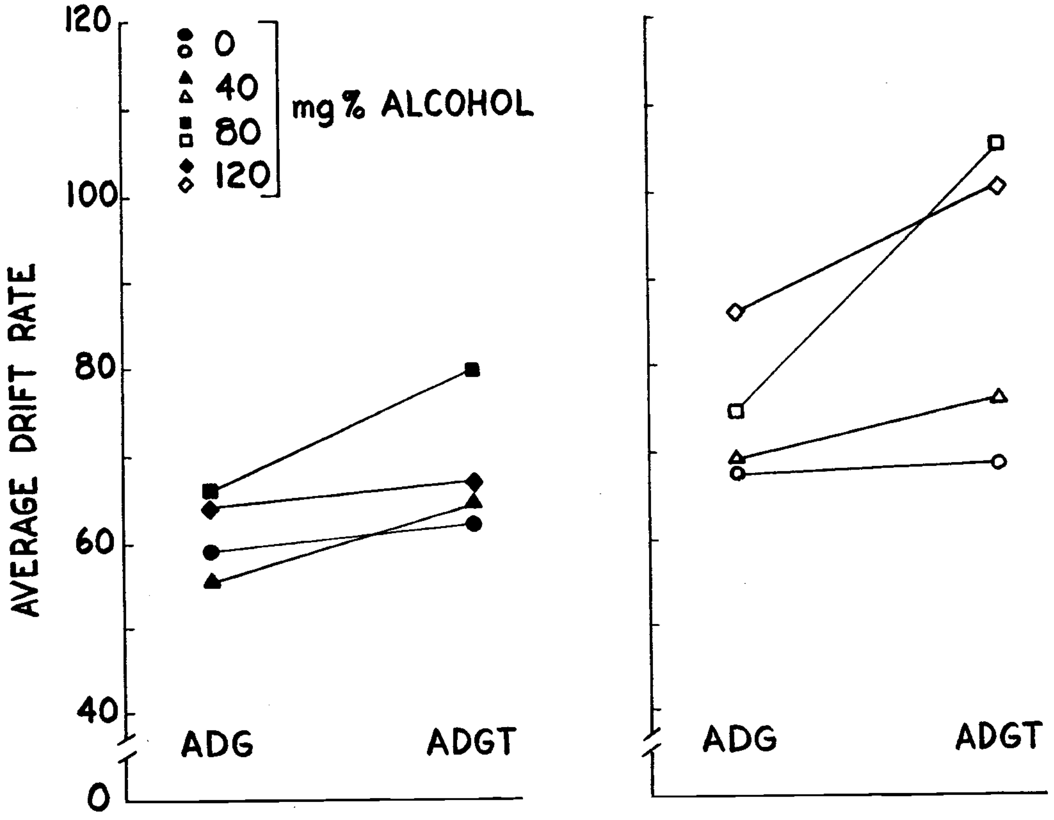
No significant effects of alcohol were found in glide path tracking errors (DG,DGT,DGM) by the experienced pilots, nor was their mean tracking variability (SG,SGT) affected. The inexperienced pilots, on the other hand, demonstrated quite a different picture (figure 9). Except for deviations from glide path at the outer marker (DGO), both deviations and variability were significantly affected by alcohol, and the significance of the deviations increased as the middle marker was approached.

Variability on glide path was remarkably consistent across alcohol levels in the more experienced group. The inexperienced pilots, on the other hand, became more variable as they approached the middle marker, the increases being proportional to the alcohol concentration.

FIGURE 10



EFFECTS OF ALCOHOL ON DRIFT RATE FROM LOCALIZER

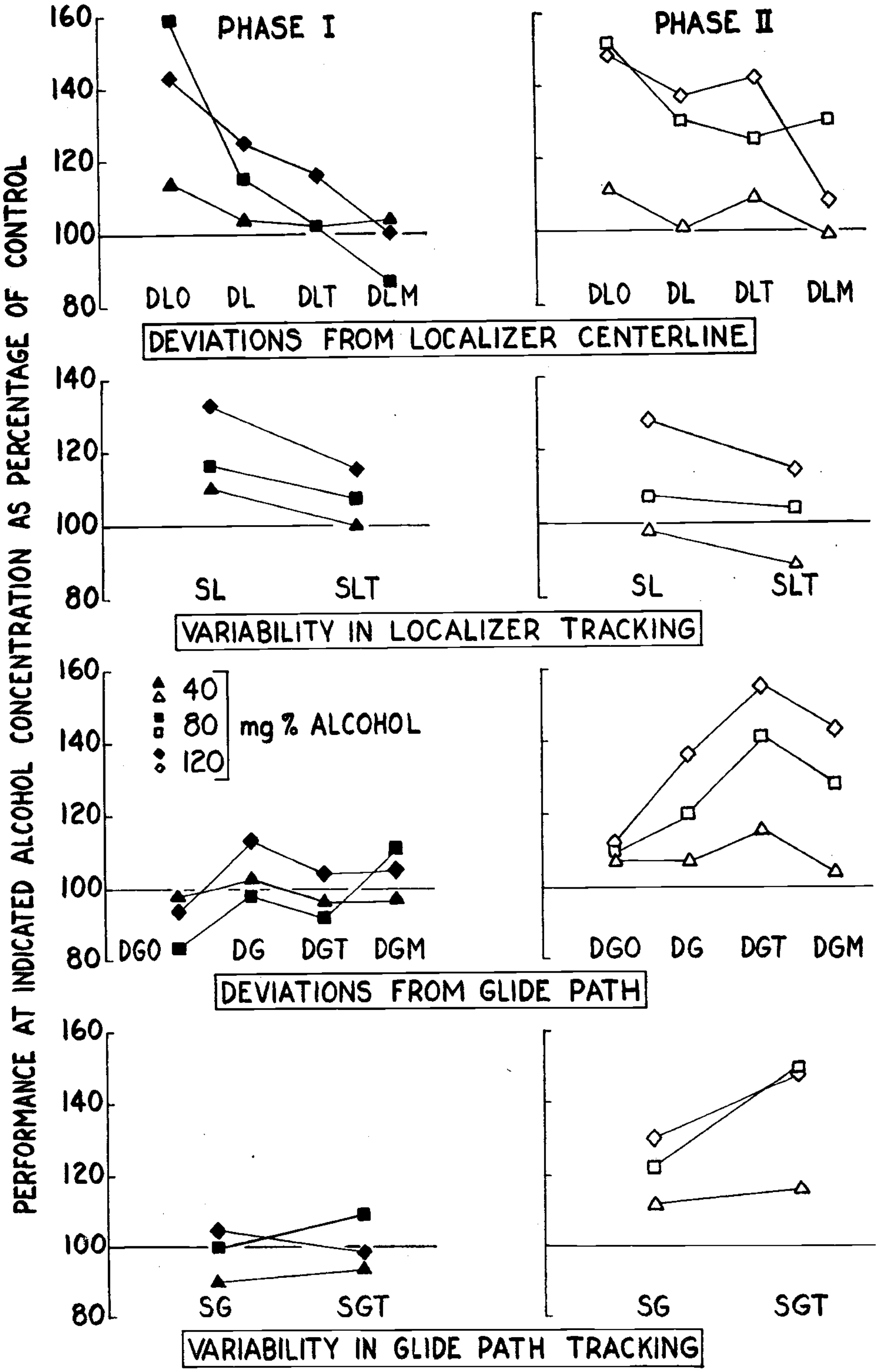


EFFECTS OF ALCOHOL ON DRIFT RATE FROM GLIDE PATH

Average rate of drift from localizer (ADL) (figure 10) was nearly significant with respect to alcohol in the experienced group. A similar non-significant trend was noted in the inexperienced pilots, who also had highly significant increases in drift rates from glide path associated with alcohol, especially during the terminal minute of their approaches. Average correction rates in both groups paralleled drift rates.

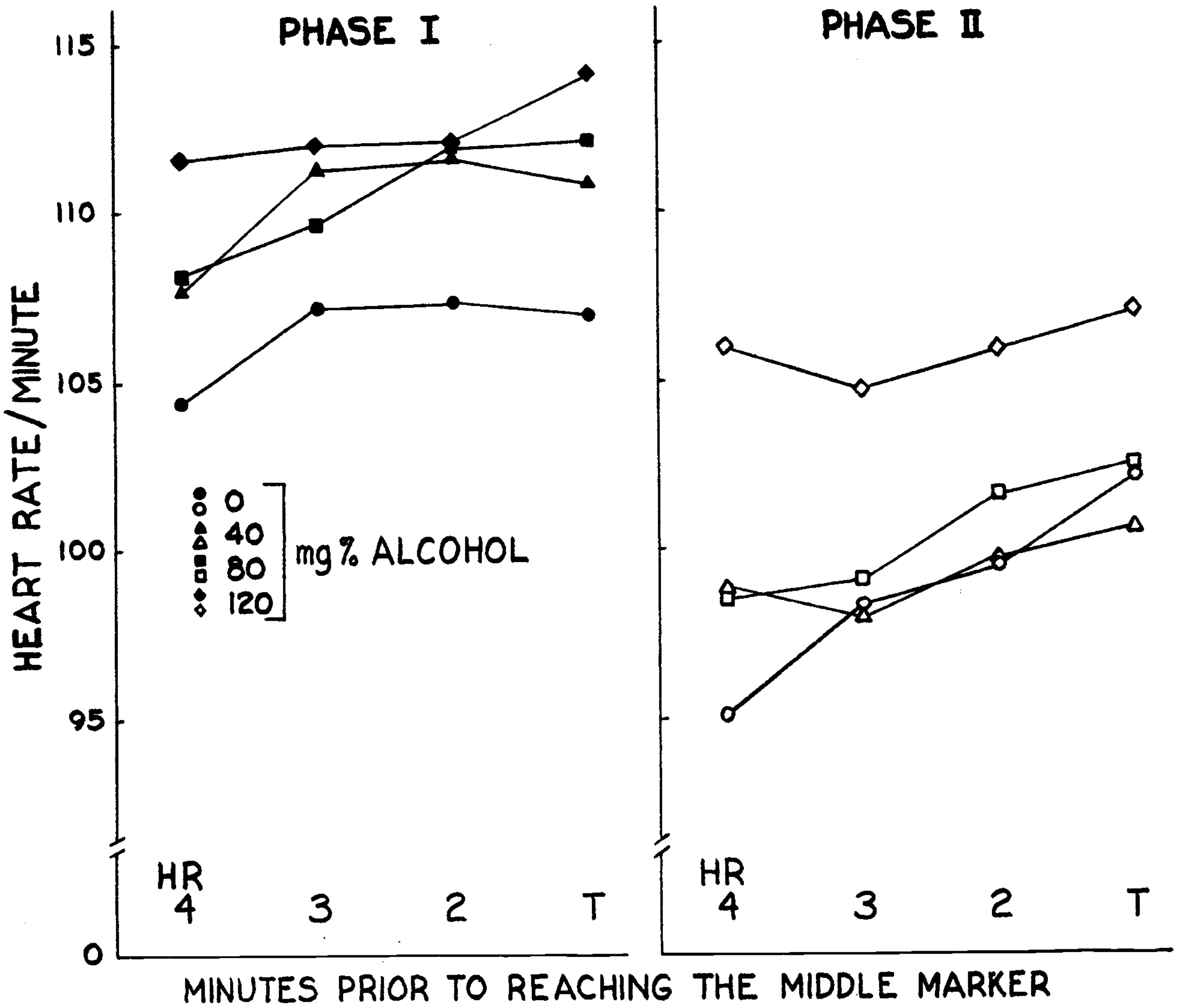
No significant effects of alcohol were noted in the airspeed data, although deviations (DS,DST) from command speed were substantially higher in the inexperienced group at 120 mg %. The lack of statistical significance in these data may have been due to oversensitive instrumentation and a consequent high noise level in the data.

FIGURE 11


PERFORMANCE AT INDICATED ALCOHOL CONCENTRATION AS PERCENTAGE OF CONTROL
PHASE I
PHASE II
160
140
120
100
80
DLO
DL
DLT
DLM
DEVIATIONS FROM LOCALIZER CENTERLINE
SL
SLT
VARIABILITY IN LOCALIZER TRACKING
▲ △ 40
■ □ 80
◆ ◇ 120
mg % ALCOHOL
DGO
DG
DGT
DGM
DEVIATIONS FROM GLIDE PATH
SG
SGT
VARIABILITY IN GLIDE PATH TRACKING

In summary, the performance of highly experienced professional pilots was minimally but significantly degraded by increasing levels of blood alcohol. Less experienced pilots showed more and larger effects associated with alcohol. There were considerable differences between the two groups. Even at the highest alcohol level studied, the more experienced pilots demonstrated an ability to control the aircraft more precisely as they approached the middle marker. The less experienced pilots also demonstrated this trend in their localizer tracking, though they compensated less effectively. In glide path tracking, the comparatively inexperienced pilots demonstrated progressive inability to cope with the task with increasing alcohol levels. Figure 11 demonstrates these trends.

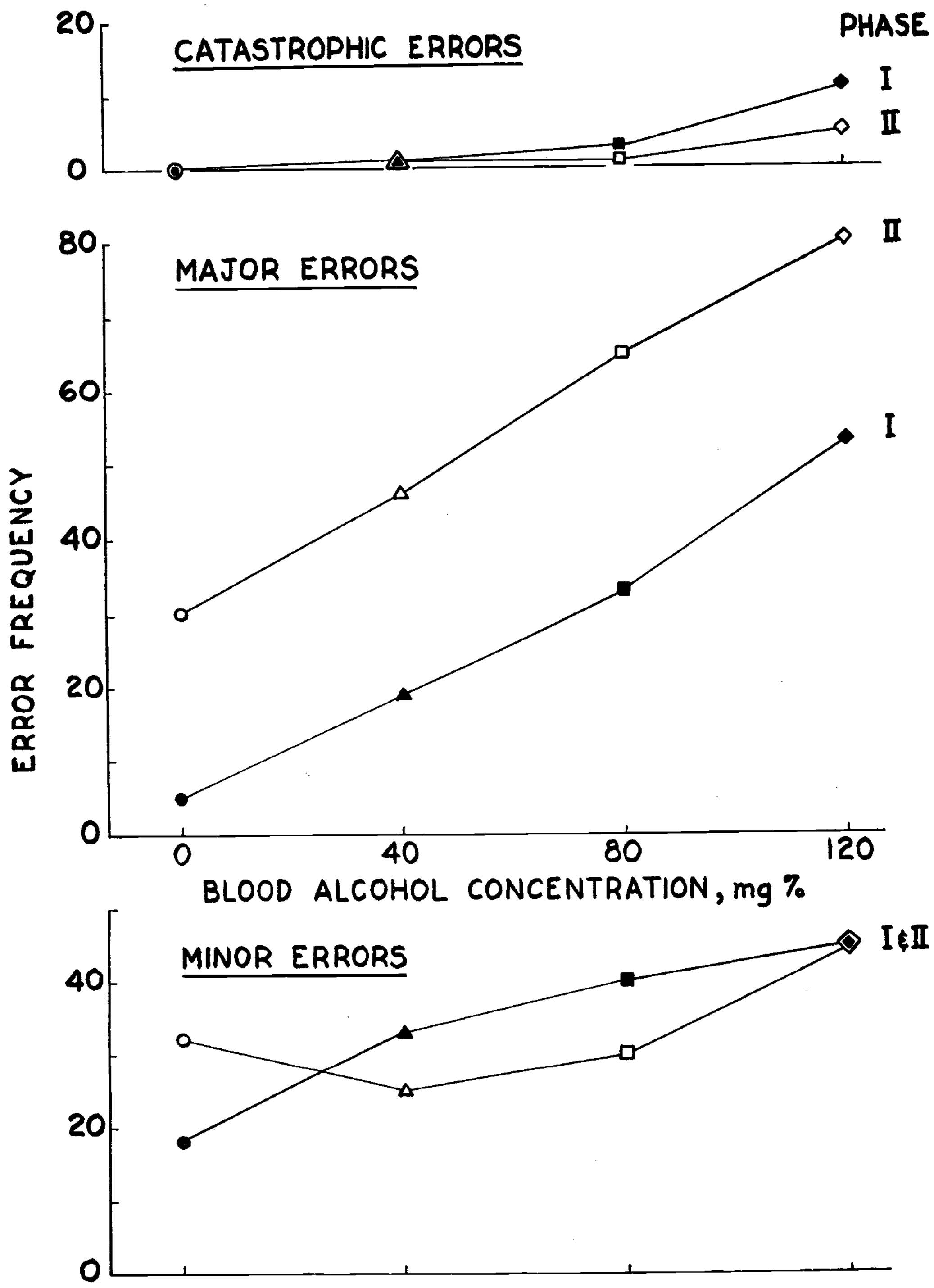
FIGURE 12



HEART RATES DURING INSTRUMENT APPROACHES

Heart rates during the approaches were directly related to alcohol levels. This was noted in both groups of pilots. The data are summarized in figure 12. It is interesting that the effect of alcohol was rather more pronounced during the first replication of the experiment than during the second in each phase. Tests for significance were not carried out on these data, but the small and consistent standard errors suggest that the differences associated with alcohol were statistically significant.

FIGURE 13



PROCEDURAL ERRORS

Subjective Data: Effects of Alcohol

Tabulation of procedural errors on a binary basis was carried out by the safety pilot at the conclusion of each phase of the experiment. The definitions used, and a few examples, have been presented above. While these tabulations cannot be said to be free of potential observer bias, since the safety pilot was aware of the alcohol levels prior to each flight, a rigid attempt has been made to exclude value judgments aside from those which impelled him to take control of the aircraft on certain occasions.

Figure 13 summarizes the error data, partitioned by phase, type and alcohol level. Errors in application or non-application of carburetor heat are excluded from the figure for reasons noted below. Several facts are immediately obvious. The number of minor errors differed significantly across alcohol levels but not between phases. The number of major errors, on the other hand, was larger in the inexperienced pilot group at all alcohol levels and became progressively larger in each group with each increase in alcohol concentration. Neither group experienced a statistically significant number of catastrophic errors except at a blood alcohol of 120 mg %, when a substantial number occurred.

Errors involving the carburetor heat control were tabulated separately after it was noted by the investigators that a few pilots contributed a disproportionate share of these errors, apparently without regard to alcohol level. Most of those errors would have been classified as major, since they involved either improper use of heat during takeoff and climb, or failure to apply heat during descent at reduced engine power settings. It is believed by the investigators that these errors were committed primarily by pilots who normally fly aircraft equipped with fuel injection engines. The trends in the data are not altered by the presence or absence of these errors, which are tabulated in table VI.

In summary: inexperienced pilots committed more procedural errors than experienced pilots at each alcohol level; the difference between the groups was significant. Both groups, taken separately or together, committed increasing numbers of progressively more serious errors with each increase in blood alcohol concentration. The likelihood that the differences occurred by chance is substantially less than 1%.

TABLE VI: PROCEDURAL ERRORS

	Phase I				Phase II			
TYPE	0	40	80	120	0	40	80	120
Minor	18	33	40	45	32	25	30	45
Major	5	19	33	53	30	46	65	80
Catastrophic	0	1	3	11	0	1	1	5
Carb. Heat	9	20	23	10	26	24	27	29
TOTAL	32	73	99	119	88	96	123	159

DISCUSSION

With respect to the primary variable under consideration here, there can be little doubt about the meaning of these data. If we assume that instrument-rated pilots, flying ILS approaches, consider the job of guiding their aircraft to a position from which a visual landing can safely be made as their primary task, then it follows that the other, discrete, procedures involved, while no less essential to safe operation, are relegated to a secondary role. The evidence is clear that this is in fact the hierarchy which exists. It is equally clear that as pilots are progressively affected by alcohol, they become progressively less able to cope with the various facets of their task, and it is the secondary tasks which suffer first and most.

This is not to say that the primary task escapes degradation. It is interesting that the experienced pilots maintained their tracking ability as well as they did, but the data from the less experienced pilots provides some clues to the stratagems employed by the former group. We see, for instance, virtually no effects of alcohol on glide path tracking. The Cessna 172 has a fixed pitch propellor and thus has a degree of longitudinal stability not found in more complex aircraft with constant-speed propellors. The extraordinarily constant deviations and variability with respect to glide path suggest that the experienced pilots recognized and made good use of this stability, thus making more time and attention available for localizer tracking. Time-sharing is known to be affected by alcohol (13).

The effect of this is seen in the localizer data at the higher alcohol levels. The experienced pilots had smaller deviations, particularly during the last minutes of the approaches, though their initial deviations were only slightly less than those of the less experienced pilots, who actually tracked the localizer more accurately when sober.

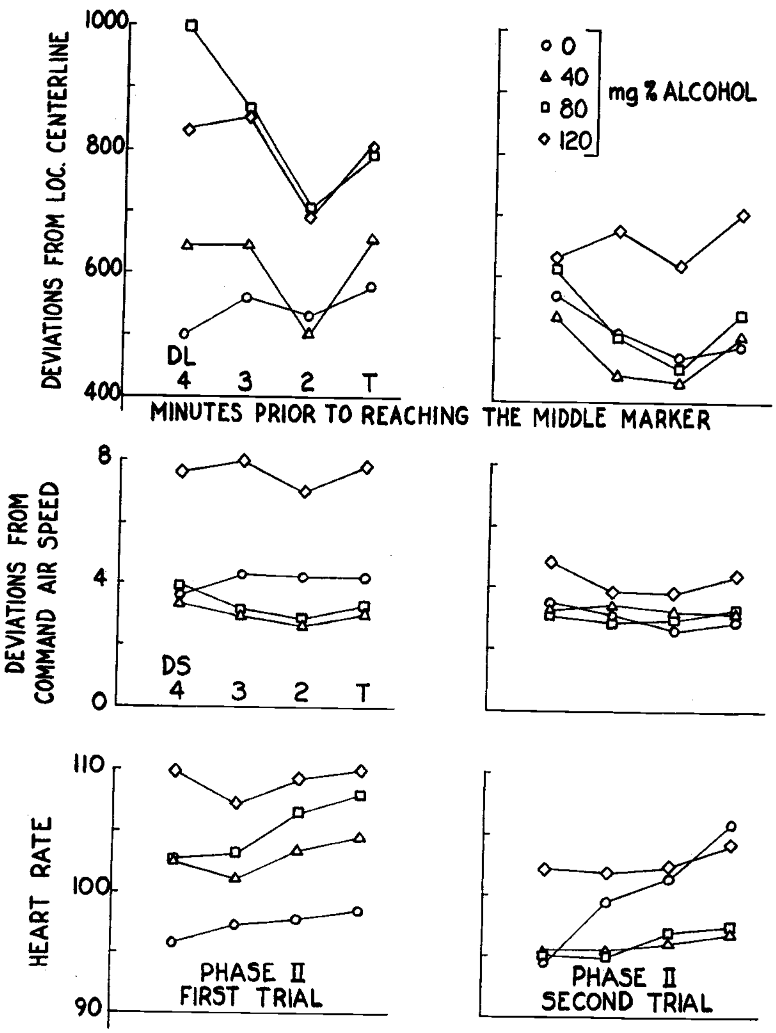
We also observe that the drift rates of the experienced pilots were lower than those of the inexperienced group at all alcohol levels. This may be due either to more rapid and frequent cross-checking of the instruments or to better directional control by the former group. Whatever the cause, they had more time in which to make corrections, which could be, and were, of small magnitude.

The experienced pilots, then, appear to have allowed the airplane to do a considerable part of their glide path tracking, while they concentrated on the localizer. Even when they were severely affected by alcohol, they were able, because of this strategy and their greater experience, to maintain lateral track fairly effectively.

The inexperienced pilots, possibly because they were not aware of the longitudinal stability of the airplane, attempted to fly both axes of the tracking task. When affected by alcohol, their performance decrements were more marked in both axes as a result. The more sensitive task, glide path tracking, suffered proportionately more, especially during the terminal phases of the approaches. The higher variability suggests as well that these pilots were working considerably harder, but they consistently lost rather than gained by their greater effort. That they had less time to devote to the secondary tasks is quite obvious in the error data.

It is especially noteworthy that there were no marked differences in tracking between the two groups during control flights. The differences became obvious when the pilots were operating under stress. The heart rate data reinforce this view. It is also instructive to note that no very marked learning effects were apparent in the inexperienced group during control flights. There were some considerable differences, however, in the decrements caused by alcohol between the first and second replications of the experiment (figure 13). It would appear from these data that these pilots benefitted considerably from their first exposure to the experiment; again, the heart rates support this interpretation.

FIGURE 14



ATTENUATION OF ALCOHOL EFFECTS BY REPLICATION

The safety pilot in these experiments was an experienced flight instructor. While his summary comments are not susceptible to quantitative evaluation, they are nonetheless valuable for the insight they provide as to the type and degree of decrements we may expect in the pilot who is affected by ethyl alcohol.

The secondary tasks involved in instrument flight begin to be neglected as pilots become less able to cope with all of the tasks at hand. Our experienced pilots managed their primary task without observable decrements at low levels of alcohol, but even at 40 mg % they no longer coped satisfactorily with carburetor heat, radio frequency selection, flap positions and ATC calls and instructions.

A very common error involved the misuse of carburetor heat. The subjects would either neglect its use during flight at low power settings, (a major error) or neglect to shut it off during ground taxi (a minor error). Several took off and tried to climb at full throttle with full heat applied. One 6,000 hour pilot examiner allowed the engine to ice to the point of severe roughness and power loss before he took corrective action.

A second common error involved the flaps. In a number of instances, flaps were not retracted after intermediate landings; shortly thereafter, the subjects tried to take off with the flaps still down.

The catastrophic errors, while few, were very serious. In one case, an experienced pilot became disoriented and lost control of the airplane. The safety pilot restored the airplane to level flight for a few moments, after which the subject was able to resume flying. In a number of cases, subjects neglected the glide path and flew almost into the ground several miles short of the runway threshold, requiring the safety pilot to take control. The third catastrophic error which was recurrent involved either excessive sink rates just prior to landing or attempts to land on the nose gear (failure to flare). In three cases, subjects left the prepared surface of runways or taxiways unintentionally.

The Cessna 172 is a simple, rugged, easy to fly airplane with the least complex systems of any modern aircraft. Had the research vehicle been a more complex machine, the number of errors in management of fuel system, propellor controls, retractible landing gear and flaps would undoubtedly have been still larger.

SUMMARY AND CONCLUSIONS

This experiment involved exposure of 16 instrument-rated pilots to four blood concentrations of ethyl alcohol, 0, 40, 80 and 120 mg %, and observation of their ability to fly a light aircraft by reference to instruments. Objective data were collected on tape during instrument approaches to ILS minimums; subjective data were collected by a safety pilot throughout the flights. Blood alcohol levels were estimated by analysis of the alcohol content of expired air.

The following conclusions are drawn from these data:

1. When sober, the inexperienced pilots were less proficient in glide path tracking and were more variable. They also committed more procedural errors.

2. At the lowest level of alcohol studied, 40 mg %, both groups demonstrated significant increases in the number and potential seriousness of their procedural errors. Minor decrements in ILS tracking were observed in the inexperienced pilots at this level.

3. At higher alcohol levels, performance decrements were observed in both groups; these were minor in the experienced pilots but became substantial in the less experienced pilots whose ability to track the vertical component of the ILS suffered severely. The number of major procedural errors continued to rise almost linearly in both groups.

4. At a level of 120 mg % of blood alcohol, catastrophic failures began to occur. The safety pilot was required to take control of the aircraft on 16 occasions during 30 flights at this level. Two pilots became incapacitated in flight as a result of severe vertigo, nausea and vomiting while flying by reference to instruments.

5. It is concluded that significant degrees of performance impairment exist in qualified pilots under the influence of 40 mg % blood alcohol, half the minimum level accepted by any jurisdiction as evidence of intoxication. We have not determined a blood alcohol level at which no significant impairment exists in flight.

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APPENDIX 1

AIRCRAFT INSTRUMENTATION

The Cessna 172 used in this research contains the following flight equipment:

A. Instruments (lighted)

1. Air speed indicator
2. Turn and bank indicator
3. Altimeter
4. Rate of climb indicator
5. Directional gyro
6. Artificial horizon
7. King KI-211 VOR-LOC-GS cross-pointer indicator
8. Tachometer
9. Oil temperature gauge
10. Oil pressure gauge
11. Fuel quantity gauges
12. Vacuum gauge
13. Ammeter

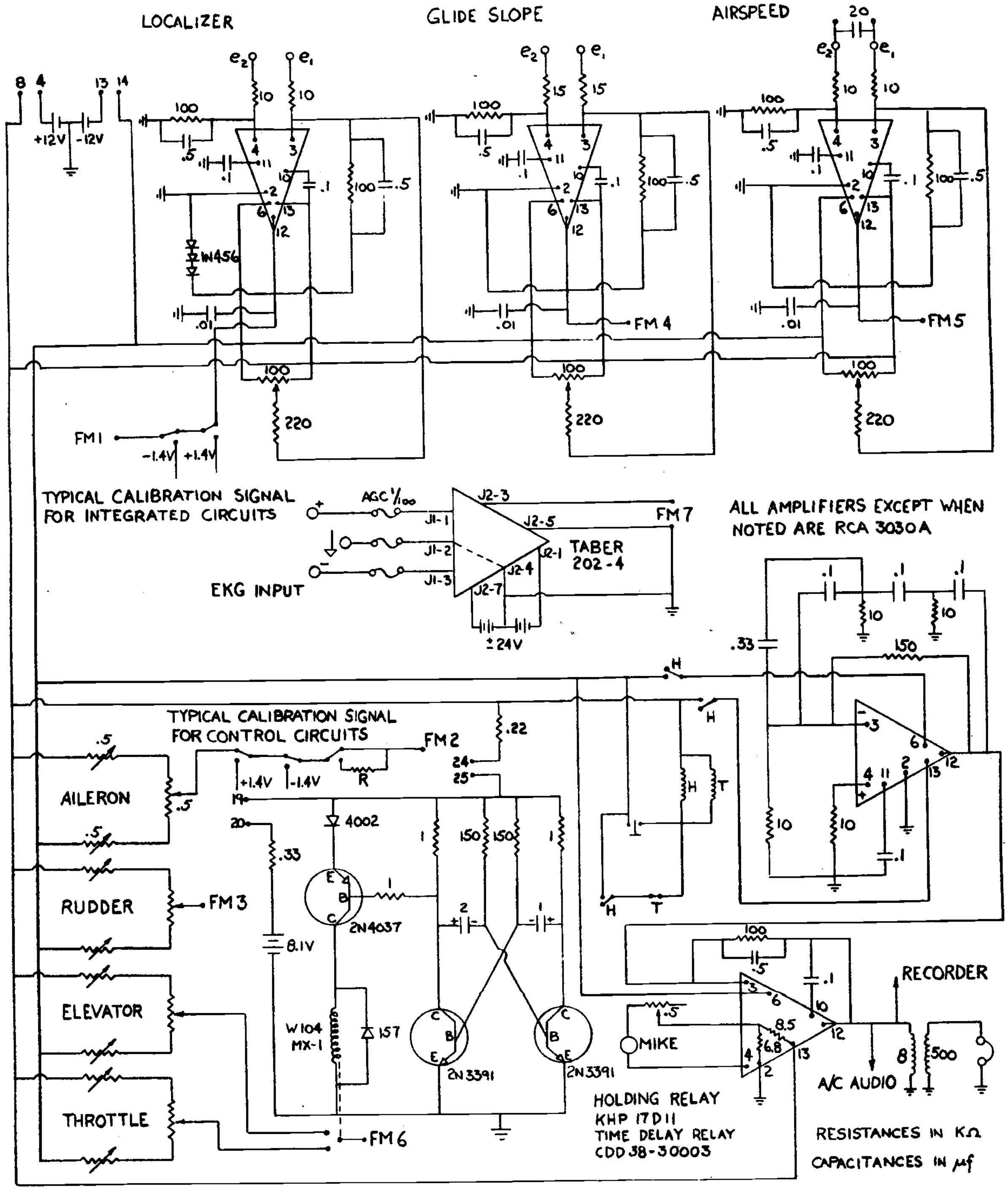
B. Lighting

1. Cockpit instruments
2. Observer (rear) station
3. Navigation lights
4. Tail-mounted stroboscopic unit (white)
5. Landing and taxi lights

The electronic system in the research vehicle (Cessna 172) provides a method of collecting the following data:

1. Localizer tracking
2. Aileron movements
3. Rudder movements
4. Glide slope tracking
5. Airspeed
6. Throttle movements
7. Elevator movements
8. EKG
9. Voice communications

FIGURE 15



SCHEMATIC DIAGRAM OF MATING UNIT

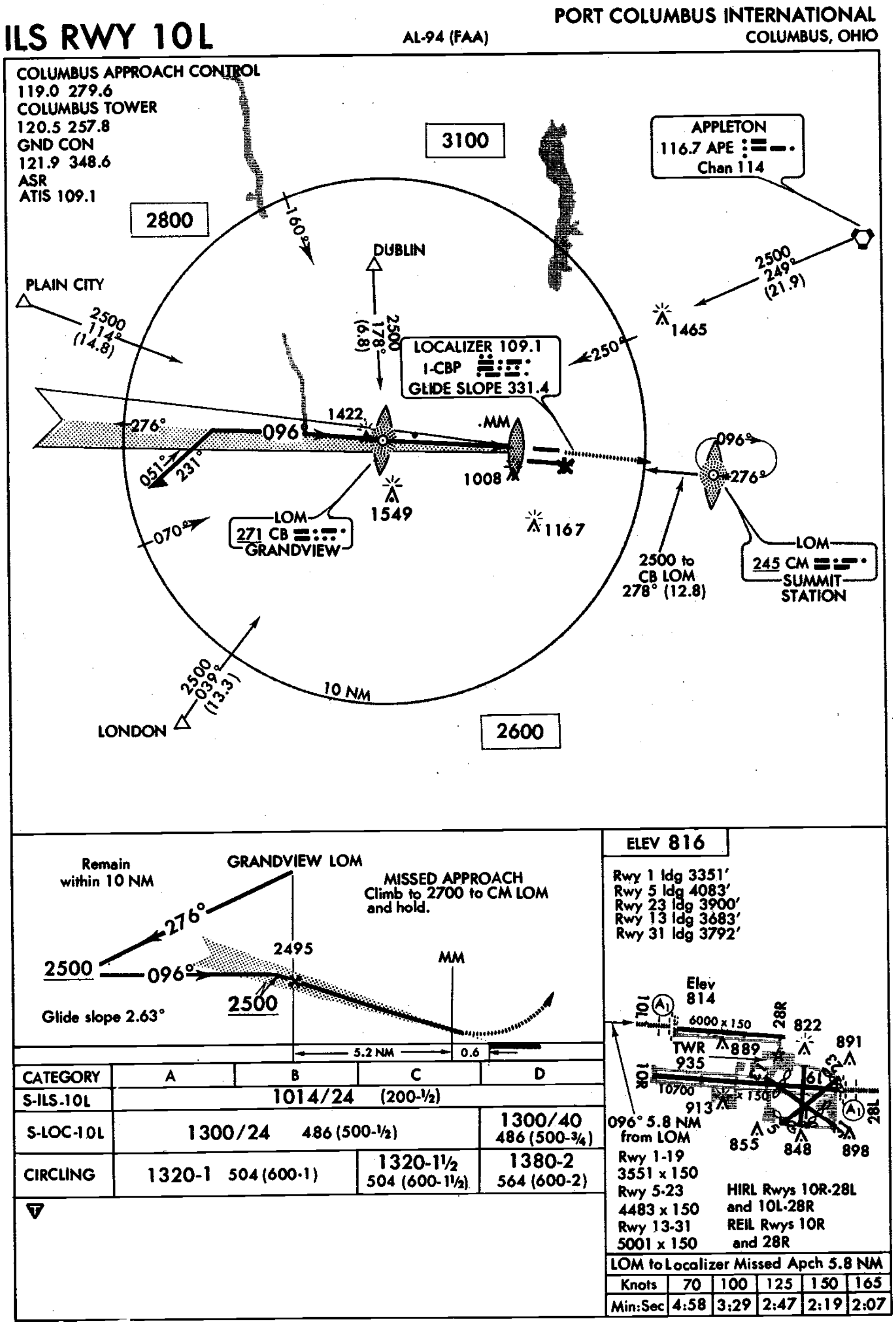
The system is operated by its own internal power supply, primarily rechargeable sealed nickel - cadmium batteries. The system may be stored and operated at temperatures of up to 120°F. The ideal temperature for storage is room temperature.

The total system for data collection consists of the following component parts:

1. Glide Slope and Localizer System consisting of a King KX160 nav/com unit, a King KI211 indicator, and a King KMA12 marker beacon receiver - audio amplifier.
2. Control deflections are measured by Bourns 3510S-20-501 three-turn potentiometers driven by the control cables.
3. A flow meter measures air speed (the device used was a model 55A1 Air Velocity Meter (Flow Corp.) powering a hot wire anemometer over which air was drawn by a venturi mounted in the slipstream).
4. A Lockheed Model 117 seven channel FM tape recorder.
5. A recorder mating box between the various pickups and the tape recorder. A schematic of the mating unit is shown in fig. 15.
6. A push-button device to signal when the aircraft is over the outer and the middle markers.

The total system draws less than 1 ampere and does so only when all component parts are connected and the device is in use.

Figure 16



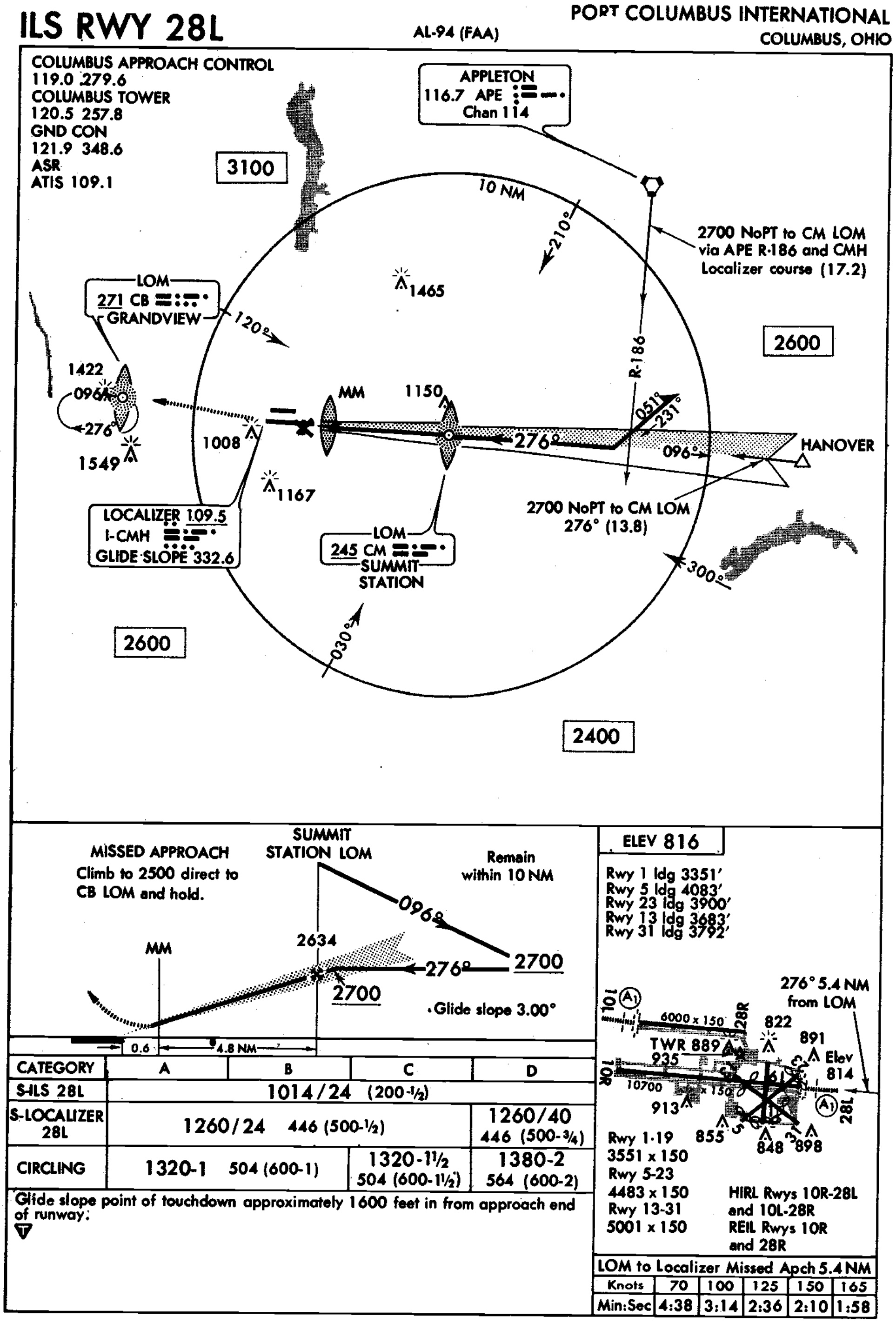
CATEGORY	A	B	C	D
S-ILS-10L	1014/24 (200-½)			
S-LOC-10L	1300/24 486 (500-½)			1300/40 486 (500-¾)
CIRCLING	1320-1 504 (600-1)		1320-1½ 504 (600-1½)	1380-2 564 (600-2)

LOM to Localizer Missed Apch 5.8 NM

Knots	70	100	125	150	165
Min:Sec	4:58	3:29	2:47	2:19	2:07

APPROACH CHART: RUNWAY 10 LEFT

Figure 17



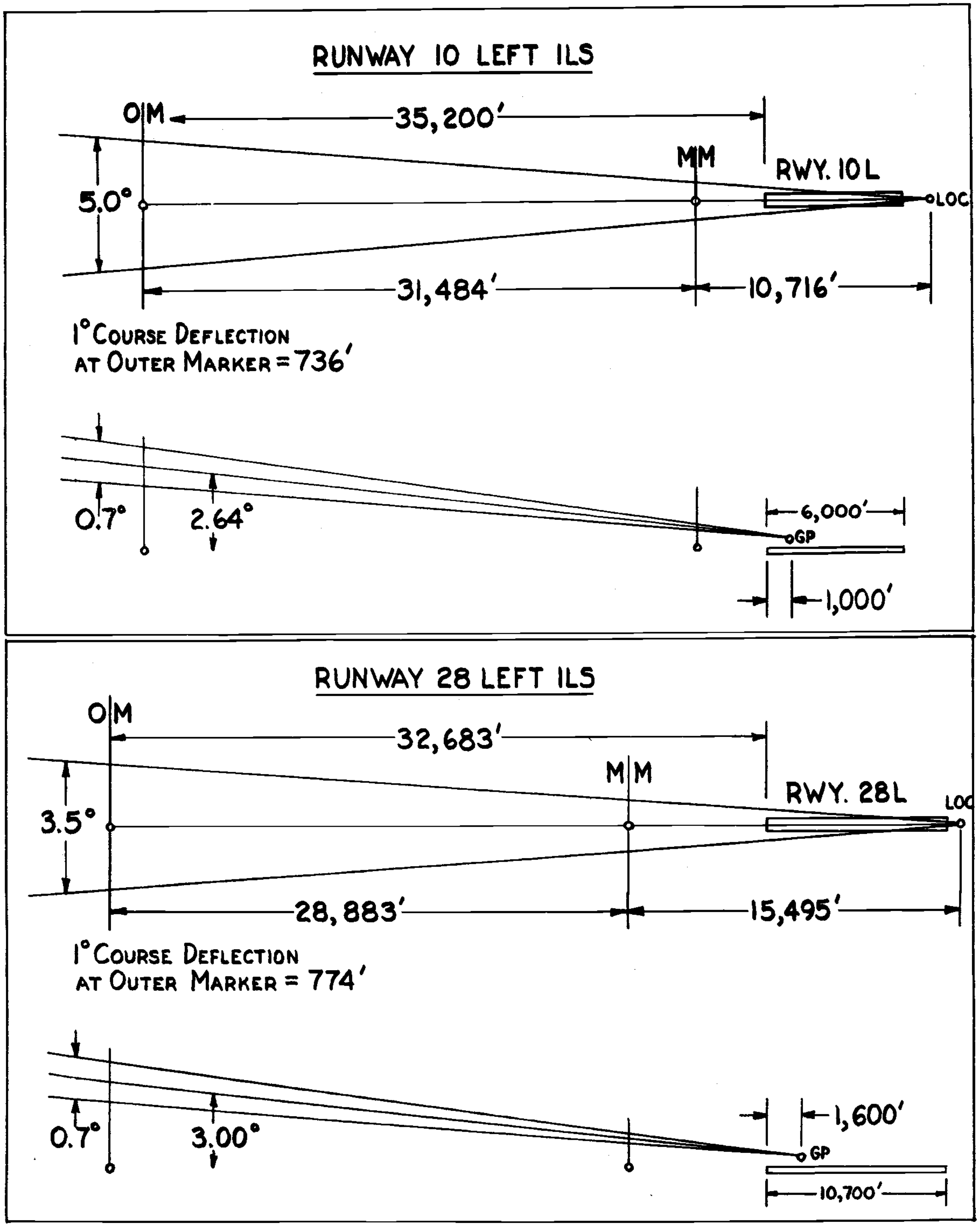
CATEGORY	A	B	C	D
S-ILS 28L	1014/24 (200-½)			
S-LOCALIZER 28L	1260/24 446 (500-½)			1260/40 446 (500-¾)
CIRCLING	1320-1 504 (600-1)		1320-1½ 504 (600-1½)	1380-2 564 (600-2)

Glide slope point of touchdown approximately 1600 feet in from approach end of runway.

LOM to Localizer Missed Apch 5.4 NM					
Knots	70	100	125	150	165
Min:Sec	4:38	3:14	2:36	2:10	1:58

APPROACH CHART: RUNWAY 28 LEFT

FIGURE 18



INSTRUMENT LANDING SYSTEM GEOMETRY (NOT TO SCALE)

Exemption No. 821

UNITED STATES OF AMERICA
FEDERAL AVIATION ADMINISTRATION
DEPARTMENT OF TRANSPORTATION
WASHINGTON, D. C.

* *

In the matter of the petition of

OHIO STATE UNIVERSITY
AVIATION MEDICINE RESEARCH LABORATORY

for an exemption from section 91.11(a)(1)
and (b) of Part 91 of the Federal
Aviation Regulations

* *

Regulatory Docket No. 8895

GRANT OF EXEMPTION

The Director, Ohio State University Aviation Medicine Research Laboratory has requested a waiver of FAR 91.11(a)(1) and (b) in order to undertake a research project.

FAR 91.11(a) and (b) prohibit a person from acting as a crewmember of a civil aircraft while under the influence of intoxicating liquor and, except in an emergency, prohibit the pilot of a civil aircraft from allowing a person who is obviously under the influence of intoxicating liquors or drugs (except a medical patient under proper care) to be carried in the aircraft.

The Ohio State University Aviation Medicine Research Laboratory has entered into a contract with the FAA Civil Aeromedical Institute, Office of Aviation Medicine, to determine the effects of low blood alcohol concentrations upon pilot performance.

Specifically, the research project would produce in certain pilots various blood alcohol levels up to, but not beyond, the lower limit (150 mgm %) considered sufficient to support a legal determination of drunkeness on a prima facie basis in most states for automobile drivers. These pilots would then fly a Cessna 172 airplane in accordance with a prescribed program and their performance would be measured objectively by on-board recording devices. The program will require an instrument flight, followed by a number of ILS approaches at the Port Columbus International Airport, during the course of this evaluation of pilot performance.

In consideration of the foregoing, I find that a grant of the exemption requested would not adversely affect safety and would be in the public interest, provided appropriate conditions and limitations are imposed. Therefore, pursuant to the authority contained in §§ 313(a) and 601(c) of the Federal Aviation Act of 1958, which has been delegated to me by the Administrator (14 CFR 11.53), an exemption from FAR 91.11(a)(1) and (b) is hereby issued to Ohio University Aviation Medicine Research Laboratory to the extent necessary to authorize designated persons to pilot a Cessna 172 airplane, N530SU, while under the influence of intoxicating liquor and to authorize the pilot in command of the airplane to permit such intoxicated persons to be carried in the airplane in carrying out a research project under a contract between the Ohio State University and the FAA Office of Aviation Medicine, subject to the following conditions and limitations:

1. Each pilot designated as a subject for testing and evaluation shall have an instrument rating.

2. On each flight of the airplane there shall be on board, in addition to the designated subject pilot, a certificated instrument flight instructor who shall be the pilot in command of the airplane and occupy the right seat, which shall have fully functioning dual controls. In addition, a qualified flight surgeon shall occupy the rear seat of the airplane on each flight.

3. The flight surgeon or pilot in command shall terminate any flight of the airplane if it appears to either of them at any time that continuation of the flight is likely to create a hazard to the safety of the Cessna airplane and its occupants or of other persons or property.

4. The flight surgeon on each flight of the airplane shall carry medical and physical means to restrain the designated subject pilot in the event such action becomes necessary.

5. The airplane shall be fully equipped for instrument flight, with the necessary radio navigational aids appropriate to the area, and with a stroboscopic anticollision light, all of which shall be in operable condition during flight.

6. Each flight of the airplane shall originate and terminate at the University's airport, and shall be conducted under VFR weather conditions.

7. Each flight of the airplane shall be conducted in accordance with the instrument flight rules of the Federal Aviation Regulations and during the course of each flight radio contact shall be maintained at all times with local radar approach control.

8. Each flight shall be coordinated with the FAA local GADO and subject to any additional conditions or limitations imposed by that office in the interest of safety.

This exemption shall terminate one year from its effective date or upon completion of the research project involved, whichever occurs first, unless sooner superseded or rescinded.

James F Rudolph
Director
Flight Standards Service

Issued in Washington, D.C., on MAY 20 1968

APPENDIX 3

EXPERIMENTAL PROTOCOLS

Phase I
1969 Unless Noted

Subject	Run # 1	Run # 2	Run # 3	Run # 4	Run # 5	Run # 6	Run # 7	Run # 8
1	10/11/68 0	10/29/68 40	11/5/68 80	11/29/68 120	12/6/68 0	12/30/68 40	1/3 80	omitted
2	10/22/68 80	11/4/68 0	11/14/68 120	1/2 40	1/14 40	omitted	2/3 0	2/10 80
3	10/17/68 120	10/31/68 80	12/9/68 40	12/12/68 0	12/16/68 120	1/7 80	2/4 40	2/7 0
4	10/12/68 40	11/1/68 120	11/8/68 0	12/2/68 80	12/10/68 80	12/19/68 0	1/10 120	1/13 40
5	2/14 0	2/21 80	3/7 120	3/14 40	3/21 40	4/4 80	4/11 120	4/15 0
6	2/20 80	3/4 40	3/17 0	4/7 120	4/19 0	4/21 120	4/24 40	5/20 80
7	3/6 40	3/13 120	3/31 80	4/10 0	5/19 80	5/28 40	6/3 0	6/5 120
8	3/18 120	4/3 0	4/22 40	5/1 80	5/12 120	5/26 0	6/2 80	6/6 120

Phase II
1970 Unless Noted

Subject	Run # 1	Run # 2	Run # 3	Run # 4	Run # 5	Run # 6	Run # 7	Run # 8
1	1/30 120	2/2 80	2/10 40	2/16 0	2/20 120	3/2 80	3/6 40	3/30 0
2	2/3 0	2/13 40	2/15 80	2/19 120	2/23 0	2/26 40	3/1 80	3/10 120
3	5/19 40	5/21 120	5/26 0	5/29 80	6/1 80	6/7 0	6/12 120	6/19 40
4	5/28 80	6/2 0	6/4 120	6/8 40	6/11 40	6/18 120	7/7* 0	6/23 80
5	8/6 0	9/11 120	9/15 80	9/20 40	9/22 40	9/25 80	9/29 120	10/1 0
6	8/2 80	8/7 40	8/13 120	9/18 0	9/21 0	10/2 120	11/3 40	11/17 80
7	9/28 120	10/5 0	10/8 40	10/15 80	11/5 80	11/9 40	11/13 0	11/16 120
8	11/10 40	11/19 80	11/24 0	12/4 120	12/15 120	12/28 0	1/1/71 80	1/12/71 40

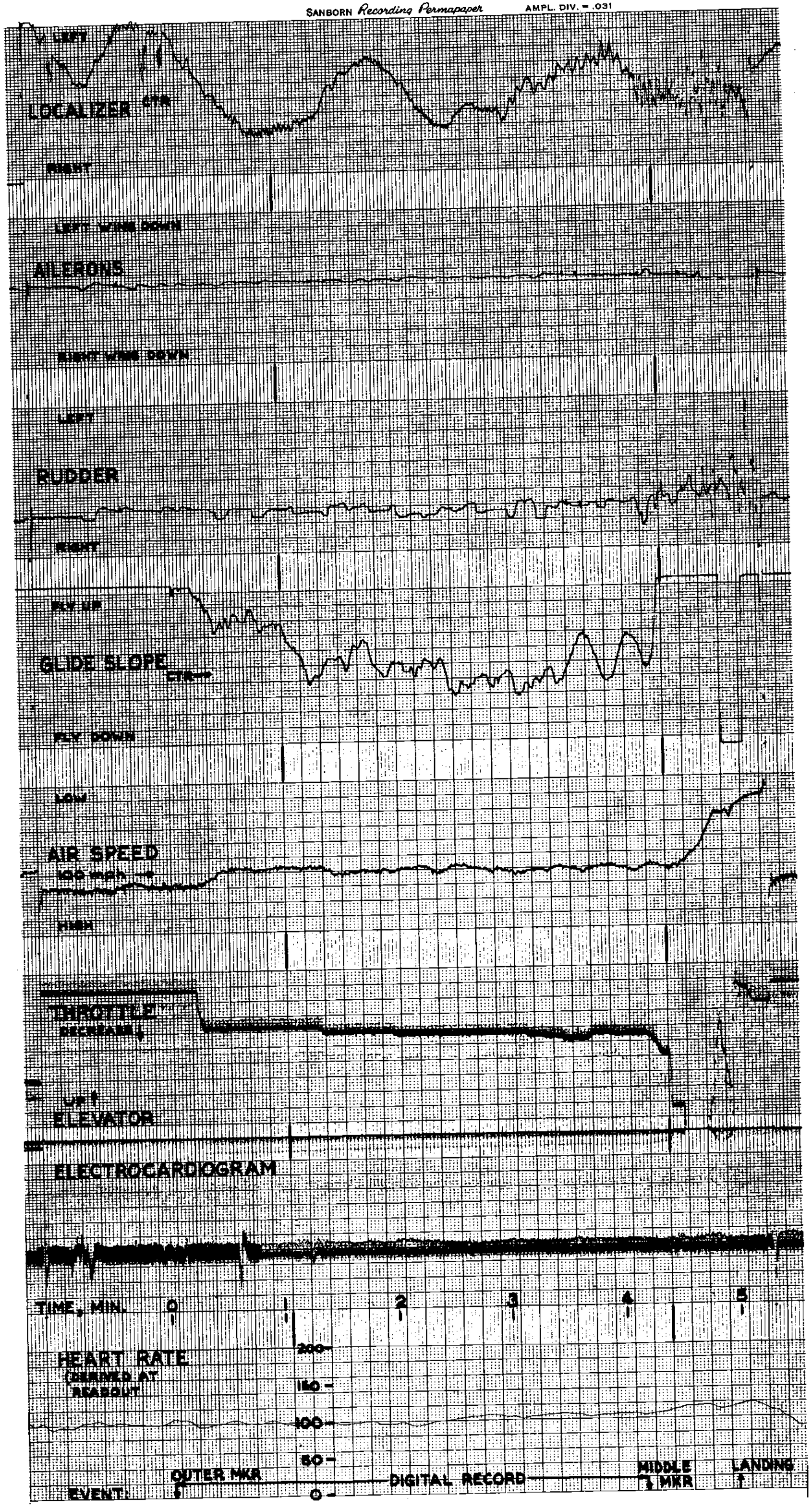
*Repeat run.

APPENDIX 4

METABOLIC DEGRADATION OF ALCOHOL

Phase	#	Weight, lb.	Correlation Coefficient	Regression Equation	Slope (mg %/hr)
I	1	185	-0.94	y = 77.89 - 0.29 x	17.69
	2	150	-0.97	y = 67.22 - 0.37 x	22.14
	3	176	-0.97	y = 76.28 - 0.37 x	21.92
	4	176	-0.95	y = 69.25 - 0.27 x	16.02
	5	157	-0.91	y = 83.50 - 0.30 x	17.96
	6	170	-0.96	y = 71.79 - 0.33 x	19.94
	7	225	-0.91	y = 72.63 - 0.25 x	14.90
	8	160	-0.95	y = 83.09 - 0.30 x	17.94
II	1	170	-0.90	y = 93.62 - 0.29 x	16.74
	2	160	-0.92	y = 111.33 - 0.18 x	10.68
	3	155	-0.95	y = 84.64 - 0.28 x	16.56
	4	220	-0.98	y = 67.89 - 0.32 x	19.20
	5	155	-0.97	y = 113.56 - 0.26 x	15.48
	6	155	-0.93	y = 85.21 - 0.31 x	18.36
	7	210	-0.97	y = 83.56 - 0.32 x	17.96
	8	220	-0.96	y = 80.54 - 0.23 x	13.92

APPENDIX 5



Analog strip chart recording of an ILS approach terminating in a landing.

Sample Narrative Summary

ALCOHOL PROJECT REPORT

Subject:		Air:	Smooth
Date:		Altitude:	30.12
Alcohol:	120 mgm %	Runway:	28L
		Temperature:	36°
		Wind:	180-9

Preflight Activities: Satisfactory, but the initial takeoff was made with full heat, although it was quite obvious the aircraft required the entire length of the runway and then just barely got into the air. The subject then left the landing light on.

First Approach: Missed one radar vector completely. No carb heat on the approach. Air speed varied from 85 - 110 mph, but the landing was satisfactory.

Second Approach: No mag or carb heat check prior to takeoff. The subject overshot the localizer and just kept on going making no attempt to turn to the runway center line. The approach ultimately, however, was satisfactory after I steered him back to the centerline. The turn on the missed approach, however, was a bad slipping turn.

Third Approach: The subject climbed with full carb heat on. We overshot our target altitude by about 300 feet. We then missed one radar vector and cruised with carb heat on. The approach, however, was made without carb heat and terminated with a diving turn to the left from which the subject eventually recovered just prior to my taking control.

Fourth Approach: The subject left the landing light on. Airspeed reached 115 mph, the approach was satisfactory as was the landing, but the subject then turned off the runway onto the grass instead of the taxiway. We taxied with flaps down and carb heat on.

Flight Back to Don Scott: The subject shut off the nav lights, but the rest of the flight back was satisfactory as was the shutdown procedure.

APPENDIX 6

PRIMARY COMPUTER OUTPUT

OUTPUT BY APPROACHES

IDENT= 412

DA= 324 SEC.

LOCALIZER

LO= 649

AL= 454.47 ALT= 479.70
VL= 329663 VLT= 596299
SL= 574.16 SLT= 772.20

DL= 621.89 DLT= 757.20

NDL= 1.48 NDLT= 1
ADL= 31.25 ADLT= 0.0
ACL= -23.49 ACLT= -7.11
AMLT= -3.56

LM= 1356

DLO= 649

DLM= 1356

HR= 88.81

GLIDESLOPE

GO= 2015

AG= 823.62 AGT= 1266.39
VG= 293540 VGT= 129936
SG= 541.79 SGT= 360.54

DG= 824.92 DGT= 1266.39

NDG= 5.56 NDGT= 5
ADG= 92.14 ADGT= 130.40
ACG= -50.79 ACGT= -71.93
AMGT= 29.24

GM= 847

DGO= 2015

DGM= 847

AIRSPEED

SO= 98

AS= 95.42 AST= 96.44
VS= 4 VST= 4
SS= 2.05 SST= 2.11

DS= 4.59 DST= 3.62

SM= 98

DSO= 2

DSM= 2

DATA FOR EACH MINUTE OF APPROACH

O M	SEG	DA (sec)	AL	SL	DL	AG	SG	DG	AS	SS	DS	RA	HR
↓	6	24	102.90	356.20	292.93	1889.71	154.43	1889.71	98.06	1.07	1.94	0.61	91 10
	5	60	624.46	498.11	688.61	804.67	438.41	804.67	93.66	1.72	6.33	0.13	87.66
	4	60	702.60	331.61	702.60	559.99	366.92	561.82	95.95	1.06	4.05	-0.00	86.13
	3	60	542.20	302.39	549.99	600.40	263.31	600.40	93.59	1.01	6.41	0.12	86 75
	2	60	64.00	618.79	542.63	460.20	383.42	465.41	96.39	1.13	3.61	0.08	89 67
	1	60	479.70	772.20	757.20	1266.39	360.54	1266.39	96.44	2.11	3.62	0.31	92.93
M M	TOT	324	454.47	574.16	621.89	823.62	541.79	824.92	95.42	2.05	4.59	0.28*	88 81

*Correlation of rudder & ailerons.

APPENDIX 7

ANALYSIS OF VARIANCE

(LEAST SQUARES SOLUTION: ANOV WITH UNEQUAL CELL FREQUENCIES)

Source of Variance	Degrees of Freedom *	F Ratio Test
Subjects (S)	7	S/e
Treatments (T)	3	T/SxT
Interaction (SxT)	21	SxT/e
Replications (e)	224	
Total	255	

*Note: Degrees of freedom for replications varied due to lost data: Subjects I-1 and I-2 were flown only once at 120 mg % because of incapacitating vertigo, and airspeed data were missing or of inadequate quality in a number of flights. The actual number of degrees of freedom for each phase are shown below:

	Phase I		Phase II	
	Air speed data	All other data	Air speed data	All other data
Subjects	6	7	7	7
Treatments	3	3	3	3
Interaction	18	21	21	21
Error	145	216	168	224
Total	172	247	199	255

APPENDIX 8

DERIVATIONS OF DEPENDENT VARIABLES

Let L be the digital representation of Localizer voltage (ch.1)

" G " " " " " Glide Path " (ch.4)

" S " " " " " Air Speed " (ch.5)

" A " " " " " Aileron position (ch.2)

" R " " " " " Rudder " (ch.3)

" E " " " " " Elevator " (ch.6)

" T " " " " " Throttle " (ch.6)

" H " " " " " Electrocardiogram (ch.7)

" t_o be a time at which the outer marker is passed at the beginning of an approach; (30 sec. after the beginning of a 500 Hz signal)

" t_m be the time at which the middle marker is passed at the end of an approach; (6 sec. after the beginning of a second signal)

" n_t be the number of sample observations (digital) of some variable, x, from time t_o to time t_m

" x_i be the i-th value of a variable, x

Let S' be a speed, in miles per hour, corresponding to S and defined by equations to be furnished.

S_c is a digital representation of a calibration speed, S'_c which will be provided at the beginning of each tape.

MEASURES OF PERFORMANCE BASED ON AIRPLANE POSITION AND SPEED

VARIABLE	DESCRIPTION	SYMBOL	DEFINITION
1	INITIAL LATERAL POSITION	LO	$= \frac{\sum_{i=1}^{100} L_i}{100}$
2	INITAL VERTICAL POSITION	GO	$= \frac{\sum_{i=1}^{100} G_i}{100}$
3	INITIAL AIR SPEED	SO	$= \frac{\sum_{i=1}^{100} S_i'}{100}$
4	FINAL LATERAL POSITION	LM	$= \frac{\sum_{i=n_t-100}^{n_t} L_i}{100}$
5	FINAL VERTICAL POSITION	GM	$= \frac{\sum_{i=n_t-100}^{n_t} G_i}{100}$
6	FINAL AIR SPEED	SM	$= \frac{\sum_{i=n_t-100}^{n_t} S_i'}{100}$

7 AVERAGE LATERAL POSITION DURING APPROACH $AL = \frac{\sum_{i=1}^{n_t} L_i}{n_t}$

8 AVERAGE VERTICAL POSITION DURING APPROACH $AG = \frac{\sum_{i=1}^{n_t} G_i}{n_t}$

9 AVERAGE AIR SPEED DURING APPROACH $AS = \frac{\sum_{i=1}^{n_t} S_i'}{n_t}$

10 AVERAGE LATERAL DEVIATIONS DURING APPROACH $DL = \frac{\sum_{i=1}^{n_t} |L_i|}{n_t}$

11 AVERAGE VERTICAL DEVIATIONS DURING APPROACH $DG = \frac{\sum_{i=1}^{n_t} |G_i|}{n_t}$

12 AVERAGE AIR SPEED DEVIATIONS DURING APPROACH $DS = \frac{\sum_{i=1}^{n_t} |S_i' - 90|}{n_t}$

13 VARIANCE OF LATERAL TRACK DURING APPROACH $VL = \frac{\sum_{i=1}^{n_t} (L_i^2)}{n_t} - \frac{\left(\sum_{i=1}^{n_t} L_i\right)^2}{n_t^2}$

14 VARIANCE OF VERTICAL TRACK DURING APPROACH $VG = \frac{\sum_{i=1}^{n_t} (G_i^2)}{n_t} - \frac{\left(\sum_{i=1}^{n_t} G_i\right)^2}{n_t^2}$

15 VARIANCE OF AIR SPEED DURING APPROACH $VS = \frac{\sum_{i=1}^{n_t} (S_i'^2)}{n_t} - \frac{\left(\sum_{i=1}^{n_t} S_i'\right)^2}{n_t^2}$

16	STANDARD DEVIATION OF LATERAL TRACK DURING APPROACH	$SL = \sqrt{VL}$
17	STANDARD DEVIATION OF VERTICAL TRACK DURING APPROACH	$SG = \sqrt{VG}$
18	STANDARD DEVIATION OF AIR SPEED DURING APPROACH	$SS = \sqrt{VS}$

NOTE: VARIABLES 7-18 DEFINE BEHAVIOR OVER THE ENTIRE PERIOD OF STUDY, DA.

19	DURATION OF APPROACH	$DA = \frac{n_t \text{ OBS.}}{\# \text{OBS.}/\text{SEC.}}$ IN SECONDS
20	RUNWAY	RY: EITHER 10L OR 28L

NOTE: THE FOLLOWING VARIABLES DESCRIBE AIRPLANE BEHAVIOR DURING THE LAST 60 SECONDS OF EACH APPROACH.

LET n_a BE THE FIRST DATUM DURING THE FINAL MINUTE OF THE APPROACH

21 AVERAGE LATERAL POSITION DURING THE TERMINAL PHASE OF THE APPROACH

$$ALT = \frac{\sum_{i=n_a}^{n_t} L_i}{n_t-(n_a+1)}$$

22 AVERAGE VERTICAL POSITION DURING THE TERMINAL PHASE OF THE APPROACH

$$AGT = \frac{\sum_{i=n_a}^{n_t} G_i}{n_t-(n_a+1)}$$

23 AVERAGE AIR SPEED DURING THE TERMINAL PHASE OF THE APPROACH

$$AST = \frac{\sum_{i=n_a}^{n_t} S_i'}{n_t-(n_a+1)}$$

24 AVERAGE LATERAL DEVIATIONS DURING THE TERMINAL PHASE OF THE APPROACH

$$DLT = \frac{\sum_{i=n_a}^{n_t} |L_i|}{n_t-(n_a+1)}$$

25 AVERAGE VERTICAL DEVIATIONS DURING THE TERMINAL PHASE OF THE APPROACH

$$DGT = \frac{\sum_{i=n_a}^{n_t} |G_i|}{n_t-(n_a+1)}$$

26 AVERAGE AIR SPEED DEVIATIONS DURING THE TERMINAL PHASE OF THE APPROACH

$$DST = \frac{\sum_{i=n_a}^{n_t} |s_i'-90|}{n_t-(n_a+1)}$$

27	VARIANCE OF LATERAL POSITION DURING TERMINAL PHASE OF THE APPROACH	$VLT = \frac{\sum_{i=n_a}^{n_t}(L_i^2)}{n_t-(n_a+1)} - \frac{\left(\sum_{i=n_a}^{n_t} L_i\right)^2}{(n_t-[n_a+1])^2}$
28	VARIANCE OF VERTICAL POSITION DURING TERMINAL PHASE OF THE APPROACH	$VGT = \frac{\sum_{i=n_a}^{n_t}(G_i^2)}{n_t-(n_a+1)} - \frac{\left(\sum_{i=n_a}^{n_t} G_i\right)^2}{(n_t-[n_a+1])^2}$
29	VARIANCE OF AIR SPEED DURING TERMINAL PHASE OF THE APPROACH	$VST = \frac{\sum_{i=n_a}^{n_t}(S_i')^2}{n_t-(n_a+1)} - \frac{\left(\sum_{i=n_a}^{n_t} S_i'\right)^2}{(n_t-[n_a+1])^2}$
30	STANDARD DEVIATION OF LATERAL POSITION DURING TERMINAL PHASE OF THE APPROACH	$SLT = \sqrt{VLT}$
31	STANDARD DEVIATION OF VERTICAL POSITION DURING TERMINAL PHASE OF THE APPROACH	$SGT = \sqrt{VGT}$
32	STANDARD DEVIATION OF AIR SPEED DURING TERMINAL PHASE OF THE APPROACH	$SST = \sqrt{VST}$

Fluctuations during approach: explanatory note

When the airplane is drifting away from the command track, either laterally (L) or vertically (G), the function $\frac{d|L|}{dt}$ or $\frac{d|G|}{dt}$ will be positive. Conversely, when the airplane is returning toward command track, the sign of the derivatives will be negative. If a smoothing routine is applied to the data to minimize spurious slope changes, and a critical slope rejection routine is applied to reject effects of transmitting over the radio used for determination of L and G, the number of changes of sign will indicate the ability of the pilot to detect drift (-) and correct it. The average value of the function may also be useful. This may be different when the sign is (+) than when it is negative (-).

Since initial position (variable 1) is not always under the control of the pilot, high values of AL, DL, VL and SL may occur which are not indicative of poor performance. The use of the functions defined below will also aid in differentiating degraded performance from poor ground control leading to defective positioning of the airplane at the outer marker.

LET L' BE THE SMOOTHED AND PROCESSED VARIANT OF L

LET G' BE THE SMOOTHED AND PROCESSED VARIANT OF G

33 NUMBER OF CYCLIC DEVIATIONS FROM LATERAL TRACK

$$NDL = \frac{\text{NO. OF CHANGES OF SIGN OF } \frac{dL'}{dt} \times 60}{\text{DA, SECONDS}}$$

34 NUMBER OF CYCLIC DEVIATIONS FROM VERTICAL TRACK

$$NDG = \frac{\text{NO. OF CHANGES OF SIGN OF } \frac{dG'}{dt} \times 60}{\text{DA, SECONDS}}$$

35 AVERAGE RATE OF DRIFT FROM LATERAL COMMAND TRACK

$$ADL = \frac{\sum_{i=1}^{n} \left(\frac{d|L'|}{dt}\right)_i}{n} \quad \text{FOR } \frac{d|L'|}{dt} > 0$$

WHERE n = NO. OF POSITIVE VALUES

36 AVERAGE RATE OF DRIFT FROM VERTICAL COMMAND TRACK

$$ADG = \frac{\sum_{i=1}^{n} \left(\frac{d|G'|}{dt}\right)_i}{n} \quad \text{FOR } \frac{d|G'|}{dt} > 0$$

37	AVERAGE RATE OF CORRECTION TOWARD LATERAL COMMAND TRACK	$ACL = \frac{\sum_{i=1}^{n} \left(\frac{d\lvert L'\rvert}{dt}\right)_i}{n}$ FOR $\frac{d\lvert L'\rvert}{dt} < 0$ WHERE n = NO. OF NEGATIVE VALUES
38	AVERAGE RATE OF CORRECTION TOWARD VERTICAL COMMAND TRACK	$ACG = \frac{\sum_{i=1}^{n} \left(\frac{d\lvert G'\rvert}{dt}\right)_i}{n}$ FOR $\frac{d\lvert G'\rvert}{dt} < 0$
39	NUMBER OF CYCLIC DEVIATIONS FROM LATERAL TRACK DURING TERMINAL PHASE OF THE APPROACH	$NDLT =$ NO. OF CHANGES OF SIGNS OF $\frac{dL'}{dt}$ FROM n_a TO n_t
40	NUMBER OF CYCLIC DEVIATIONS FROM VERTICAL TRACK DURING TERMINAL PHASE OF THE APPROACH	$NDGT =$ NO. OF CHANGES OF SIGNS OF $\frac{dG'}{dt}$ FROM n_a TO n_t
41	AVERAGE RATE OF DRIFT FROM LATERAL COMMAND TRACK DURING TERMINAL PHASE OF THE APPROACH	$ADLT = \frac{\sum_{i=1}^{n} \left(\frac{d\lvert L'\rvert}{dt}\right)_i}{n}$ FOR $\frac{d\lvert L'\rvert}{dt} > 0$ WHERE n = NO. OF POSITIVE VALUES
42	AVERAGE RATE OF DRIFT FROM VERTICAL COMMAND TRACK DURING TERMINAL PHASE OF THE APPROACH	$ADGT = \frac{\sum_{i=1}^{n} \left(\frac{d\lvert G'\rvert}{dt}\right)_i}{n}$ FOR $\frac{d\lvert G'\rvert}{dt} > 0$

43	AVERAGE RATE OF CORRECTION TOWARD LATERAL COMMAND TRACK DURING TERMINAL PHASE OF THE APPROACH	$ACLT = \frac{\sum_{i=1}^{n} \left(\frac{d\lvert L'\rvert}{dt}\right)_i}{n}$ FOR $\frac{d\lvert L'\rvert}{dt} < 0$ WHERE n = NO. OF NEGATIVE VALUES
44	AVERAGE RATE OF CORRECTION TOWARD VERTICAL COMMAND TRACK DURING TERMINAL PHASE OF THE APPROACH	$ACGT = \frac{\sum_{i=1}^{n} \left(\frac{d\lvert G'\rvert}{dt}\right)_i}{n}$ FOR $\frac{d\lvert G'\rvert}{dt} < 0$
45	WEIGHTED MEAN OF 41 & 43: SIGN AND MAGNITUDE	AMLT
46	WEIGHTED MEAN OF 42 & 44: SIGN AND MAGNITUDE	AMGT

SUMMARY OF DERIVED VARIABLES

VARIABLE	SYMBOL	DESCRIPTOR
1	LO	Initial lateral position at outer marker
2	GO	Vertical position at outer marker
3	SO	Airspeed at outer marker
4	LM	Lateral position at middle marker
5	GM	Vertical position at middle marker
6	SM	Airspeed at middle marker
7	AL	Average lateral position throughout approach
8	AG	Average vertical position throughout approach
9	AS	Average airspeed throughout approach
10	DL	Average lateral error during approach
11	DG	Average vertical error during approach
12	DS	Average deviation from 90 mph IAS during approach
13	VL	Variance of lateral position
14	VG	Variance of vertical position
15	VS	Variance of airspeed
16	SL	Std. deviation of lateral position
17	SG	Std. deviation of vertical position
18	SS	Std. deviation of airspeed
19	DA	Duration of approach in seconds
20	RY	Runway used for approach
21	ALT	Average lateral position during last 60 sec. of apch
22	AGT	Average vertical position during last 60 seconds
23	AST	Average airspeed during last 60 seconds
24	DLT	Average lateral error during last 60 seconds

SUMMARY OF DERIVED VARIABLES (con't)

25	DGT	Average vertical error during last 60 seconds
26	DST	Average airspeed error during last 60 seconds
27	VLT	Variance of lateral position during last 60 seconds
28	VGT	Variance of vertical position during last 60 seconds
29	VST	Variance of airspeed during last 60 seconds
30	SLT	Std. dev. of lateral error during last 60 seconds
31	SGT	std. dev. of vertical error during last 60 seconds
32	SST	Std. dev. of airspeed error during last 60 seconds
33	NDL	Number of deviations from localizer/minute
34	NDG	Number of deviations from glide path
35	ADL	Average rate of drift (lateral)
36	ADG	Average rate of drift (vertical)
37	ACL	Average rate of correction (lateral)
38	ACG	Average rate of correction (vertical)
39	NDLT	No. of deviations (lateral) during last 60 sec of apch
40	NDGT	No. of deviations (vertical) during last minute
41	ADLT	Avg. drift rate (lateral) during last minute
42	ADGT	Avg. drift rate (vertical) during last minute
43	ACLT	Avg. correction rate (lateral) during last minute
44	ACGT	Avg. correction rate (vertical) during last minute
45	DLO	Abs. value of LO
46	DLM	$= \lvert LM \rvert$
47	DGO	$= \lvert GO \rvert$
48	DGM	$= \lvert GM \rvert$
49	AMLT	Avg. lateral movement trend during last minute
50	AMGT	Avg. vertical movement trend during last minute

NOTATION IN FIGURES AND TABLES

Solid legends: Phase I pilots: High experience

◆: 120 mg % blood alcohol
■: 80 mg % " "
▲: 40 mg % " "
●: 0 mg % " "

Open legends: Phase II pilots: Low experience

◇: 120 mg % blood alcohol
□: 80 mg % " "
△: 40 mg % " "
○: 0 mg % " "

Performance Descriptors

SL : Variability on Localizer Course
SG : " " Glide Slope
SLT: " " Loc, last minute
SGT: " " GS, last minute

DLO: Deviation from Loc at outer marker
DGO: " " GS " " "
DL : Average Localizer error
DG : " Glide path error
DL(#): (# refers to a specified minute)
DG(#): (# " " " " ")
DLM: Deviation from Loc at middle marker
DGM: " " GS " " "

ADL: Average drift rate (lateral)
ADG: " " " (vertical)
ADLT: " " " , last minute
ADGT: " " " , " "

(for complete descriptions, see pp. 56-67)

APPENDIX 9

MEAN VALUES OF DEPENDENT VARIABLES

VARIABLE	Phase I				Phase II			
	0	40	80	120	0	40	80	120
SL	505	557	584	673	603	591	645	774
SLT	445	443	476	512	474	422	493	538
SG	459	414	460	482	532	596	647	692
SGT	350	330	380	343	408	474	612	603
SS	9.7	6.1	7.7	7.9	9.8	9.8	8.8	9.9
SST	1.7	2.2	1.9	1.7	2.0	2.3	1.9	2.6
DLO	607	695	964	869	661	737	1007	985
DL	566	591	652	708	546	551	709	749
DLT	652	665	668	756	534	583	667	757
DLM	732	764	640	738	637	629	825	691
DGO	1072	1053	885	1004	925	989	1013	1033
DG	536	550	508	616	581	622	699	791
DGT	587	561	539	611	567	654	799	879
DGM	609	588	676	639	778	813	993	1114
DSO	4.4	6.0	5.9	5.5	3.8	4.5	4.6	5.2
DS	3.8	4.2	3.7	3.8	3.6	3.3	3.1	6.0
DST	3.8	4.0	3.8	3.9	3.7	3.3	3.2	6.0
DSM	3.6	3.3	4.2	3.4	3.5	3.8	3.7	6.5
NDL	.50	.46	.38	.40	.01	.04	.20	.28
NDLT	.38	.42	.31	.29	.02	.03	.22	.27
NDG	5.08	4.90	5.38	4.76	4.79	5.00	4.22	4.81
NDGT	4.59	4.11	5.05	4.18	4.45	4.14	3.92	3.89
ADL	21.8	26.7	27.2	30.0	26.9	29.0	30.7	36.0
ADLT	13.3	18.5	11.8	13.5	17.2	15.6	25.2	19.0
ACL	-22.0	-23.6	-23.8	-26.8	-26.4	-23.9	-24.9	-32.2
ACLT	-13.0	-13.9	-12.2	-12.3	-16.4	-13.0	-12.4	-16.8
ADG	59.1	55.5	65.9	63.9	67.5	68.9	74.4	85.5
ADGT	61.5	64.7	79.7	66.6	68.6	76.4	105.5	100.2
ACG	-59.4	-57.9	-64.6	-62.4	-65.2	-69.2	-76.6	-88.6
ACGT	-65.3	-59.6	-76.7	-76.3	-73.7	-83.5	-115.6	-116.5
AMLT	.15	2.28	-.18	.58	.39	1.29	6.37	1.06
AMGT	-1.92	2.56	1.51	-4.85	-2.53	-3.55	-5.04	-8.15

APPENDIX 10

DESCRIPTION OF COMPUTER PROGRAMS

A series of Fortran IV (G) computer programs has been written and used to reduce continuous analog data to a series of 51 parameters which are used as input to statistical programs.

At the time of conversion of the analog tape, the record number representing the beginning of the approach (outer marker), position at the middle marker, and time of landing or go-around is recorded and subsequently key punched as input data for the programs. Appendix 8, pp. 66-67, lists the parameters which are measured for each approach. The parameters in general are smoothed (average) values for: the entire approach, the last minute of the approach, or sequential increments of the approach. In addition, the variance and standard deviation of selected variables are calculated.

The main program reads the cards containing the information on the proper approach, time at markers, alcohol level, and subject identification and searches the master data tape until the proper data are found. A series of subroutines is then called to perform the appropriate analysis for the parameter in question. The use of these subroutines enables one to modify various parts of the programs with ease and to write common code for a large number of the 51 parameters. Among the subroutines are:

1. a data smoothing routine
2. one which counts course reversals
3. heart rate
4. multichan - separates two variables which have been recorded on one FM Channel
5. a routine to pass data from record to record
6. a slope routine
7. a summing routine
8. an absolute value routine
9. a mean and sta. deviation routine

The reduced data is printed for visual verification and review and is additionally punched on cards to be used as input to the statistical analysis programs. Appendix 6 (p. 54) contains samples of the output obtained for each approach. While the data could be written on tape, it is somewhat easier to recombine and sort the data from cards for subsequent analysis.

An analysis of variance program similar to BMDO2V but utilizing weighted means to compensate for unequal cell sizes has been employed to perform the bulk of the statistical analysis. It utilizes Dwyer's square root algorithm and includes as output:

1. cell frequencies

2. cell, marginal, and grand totals and means

3. a summary of the analysis of variance

Individual analysis of variance problems are run on 32 selected parameters from Appendix 8. Significant results from these analyses are combined with the narrative output and the resulting data interpreted. The resulting interpretation has been presented elsewhere in this report.