Journal of Criminal Law and Criminology

Volume 52
Issue 2 *July-August*

Article 9

Summer 1961

Evaluation of the Measurement of Motor Vehicle Ground Speed from Aircraft

Richard A. Myren

POLICE SCIENCE

EVALUATION OF THE MEASUREMENT OF MOTOR VEHICLE GROUND SPEED FROM AIRCRAFT

RICHARD A. MYREN

The author is currently on leave of absence from the Department of Police Administration, Indiana University, and is serving as a Consultant on Law Enforcement Programs for Children and Youth with the Children's Bureau, Department of Health, Welfare and Education, Washington. Mr. Myren was at one time associated with the Institute of Government at the University of North Carolina and during his association with Indiana University served as a Staff Member of the Center for Police Training. We are pleased to again be able to present one of his articles which should prove of interest to our police readers.—EDITOR.

Ground speed of motor vehicles has been measured from aircraft by the Indiana State Police since April 3, 1956.[1] Between June 1, 1958, and May 31, 1959, this air observation led to 3,101 arrests.[2] Convictions averaged better than 99%.[3] Despite this demonstration of faith in the accuracy of aircraft speed checking, questions which have resulted in lost cases have been raised about the human element involved.[4] The experiment described in this article was designed primarily to discover the extent and significance of human error in air speed check procedures. Secondary studies were made of the effect of experience on the error factor and of the ability of the driver of the test car to maintain his intended speed throughout the test run.

In checking motor vehicle ground speed from aircraft, the air observer records with a hand operated stop-watch the time which elapses while the vehicle covers the distance between two broad white lines painted on the highway. He then consults a printed table to determine the speed. The table is based on the simple formula: speed equals distance divided by time. Figure 1 is the table used in this experiment. If the lines are correctly spaced and the watch operating accurately, factors which easily can be controlled in an established routine, only human variables remain as possible sources of error. These human factors are:

1. The judgment of the observer as to when to start and to stop the watch;
2. The constancy of the observer's reaction time in starting and stopping the watch; and
3. The accuracy with which the observer reads and records the final stop watch setting.

Since a permanent record is made of the stop watch reading prior to consulting the table, any mistake in reading the table can easily be detected at any later time.

One familiar with air speed check procedures would expect the error attributable to the first possible source, judgment of the observer as to when to start and to stop the watch, to be very small. The white lines which are in current use are kept well painted and are wide enough, eighteen inches, to make them plainly visible from the air. From his vantage point (Figure 2), the air observer has the best possible conditions under which to make the judgment as to time for actuation of the watch. Most observers pick the time when the vehicle first obscures the view of the leading edge of the line.

These optimum conditions also minimize actual error due to the second possible theoretical source, variation in the reaction time in starting and stopping. Assuming that the decision to actuate is made at the same time in relation to the first

[1] For previous articles descriptive of the program, see Enforcement Up in the Air, TRAFFIC SAFETY, VOL. 51, No. 1, pp. 26–27 (July, 1957) and Troopers Patrol by Land, 'Sea' and Air, THE SUNDAY COURIER AND PRESS, p. 12A (October 26, 1958).

[2] Personal communication to the author from F. Sgt. Robert H. Myers, Air Section, Indiana State Police.

[3] *Ibid.*

[4] See the news stories reported in the DAILY HERALD-TELEPHONE (Bloomington, Indiana), Saturday, May 16, 1959, p. 1, column 9: "The judge cited the human factor involved and said a one-second error would make a difference of ten miles per hour," and in the NOBLESVILLE (Indiana) LEDGER, Wednesday, May 20, 1959, p. 8, column 3: "Judge.. sustained... motion for dismissal... based on the possibility of error, a second one way or the other."

FIGURE ONE

INDIANA UNIVERSITY

Official Record of Speed Test Runs

Timing Device____________Watch No.____________Date__________________Page____of____

9.9	45.45	8.7	51.72	7.5	60.00	6.3	71.43	5.1	88.23
9.8	45.92	8.6	52.33	7.4	60.81	6.2	72.58	5.0	90.00
9.7	46.39	8.5	52.94	7.3	61.64	6.1	73.77	4.9	91.84
9.6	46.87	8.4	53.57	7.2	62.50	6.0	75.00	4.8	93.75
9.5	47.37	8.3	54.22	7.1	63.38	5.9	76.27	4.7	95.74
9.4	47.87	8.2	54.88	7.0	64.28	5.8	77.59	4.6	97.83
9.3	48.39	8.1	55.55	6.9	65.22	5.7	78.95	4.5	100.00
9.2	48.91	8.0	56.22	6.8	66.18	5.6	80.36	4.4	102.27
9.1	49.45	7.9	56.96	6.7	67.16	5.5	81.82	4.3	104.65
9.0	50.00	7.8	57.69	6.6	68.18	5.4	83.33	4.2	107.14
8.9	50.56	7.7	58.44	6.5	69.23	5.3	84.90	4.1	109.76
8.8	51.14	7.6	59.21	6.4	70.31	5.2	86.54	4.0	112.50

RUN NO.	DIRECTION	SECONDS	SPEED	REMARKS

Timer's Signature______________________Witness's Signature__________________

Remarks:____

Figure 1

Figure 2

This illustration shows the observer's view of the test strip with a test car making a run. Note the clear white lines at the ends of the strip.

and second lines, there is still a possibility that the time lapse in carrying out that decision may be different. The comfort and lack of distraction of the aerial operator would lead one familiar with the system to expect that this error, too, would be very small.

This leaves for consideration the third possible source of human error: mistake in observing and recording the final stop watch reading. The observing error would most probably be one of one tenth of a second with a possible error of a complete second. A full second error would give a speed variation of such magnitude (nine to twenty miles per hour in the 75 to 84 mile per hour category where most arrests occur)[5] as to be readily detected by a trained observer. Such an error would probably also be apparent to the officer on the ground with whom the air observer is working. A more frequent probable source of error would be mistakes in reading of one tenth of a second. Such an error would be so small in terms of miles per hour (1.2–1.4 miles per hour in the 75 to 84 mile per hour category) that it would not be noticed by either the air observer or his partner on the ground. One of the standard operating rules in air speed check procedure as adopted by the Indiana State Police[6] dictates that in any observation in which the reading exceeds a given tenth of a second the result shall be recorded at the next higher tenth of a second, no matter how small the excess.

It should be noted that this operating rule as to reading tenths of a second operates in favor of the motorist. In the 75 to 84 mile per hour range, the average advantage is 0.7 miles per hour. The motorist also benefits from the companion operating

[5] Between January 1, 1958 and June 30, 1959, 2433 speeding arrests were made by the Indiana State Police using this procedure. Of these, 2,288 or 94.1% were in the 75–84 mph range and 2,391 or 98.2% were at speeds in excess of 75 mph. (Personal communication to the author from Capt. R. Max Branch Field Captain, Indiana State Police.)

[6] Following is the Standard Operating Procedure For Aircraft Speed Checks adopted by the Indiana State Police:

"In order that a standard may be established in air operations, the following procedures will be used in speeding arrests effected from aircraft:

1. Establish that the ceiling and visibility are at least 2,000 feet and five miles.
2. Operate aircraft at altitude of 1,000 feet above the surface.
3. Clock vehicles using the front as a reference except when the aircraft is in the 4 to 8 o'clock relative position of the vehicle, then use the rear of the vehicle as the reference.
4. Actuate the stop watch at both ends of the test strips when the leading edge of the automobile first obstructs the view of the white lines, or when using the rear, when the vehicle passing over the line first reveals the first full of the line.
5. Read the watch to the full tenth of a second beyond the actual reading. *Do not* read hundredths of a second. *Do not* round readings off to the last full tenth of a second, no matter how little the time is in excess of that last full tenth of a second. Record the next higher tenth of a second, no matter how slight the excess.
6. Alert ground units: keep eyes on violator until stopped.
7. Record the reading in seconds and tenths of a second on the chart.
8. Check the speed indicated by the recorded number of seconds and call this speed to the officer on the ground.
9. Check the recorded reading against the stop watch.
10. Record the speed after consulting the chart, and complete the other portions of the arrest record.
11. Clear the stop watch.
12. Repeat the process."

rule under which speeds are read only to the last whole mile per hour. Any excess, no matter how close to the next mile per hour, is dropped. This average amounts to 0.5 miles per hour. The sum of these average built in advantages to the motorist is 1.2 miles per hour. The significance of this advantage is pointed out below in the discussion of the experimental results.

In addition to the possibility that the observer might introduce error due to judgment, reaction time, and mistaken readings, it would be possible for him to record his readings incorrectly. Care in operation which requires, for example, that the recording be checked back against the reading before the stop watch is cleared is one safeguard against such mistakes. Another is training which emphasizes care in recording as well as in following the standard operating procedure. The marketing of a simple recording stop watch would eliminate this problem.

Design of the Experiment

This experiment was conceived, designed and carried out by the author and his colleagues in the Department of Police Administration of Indiana University with the cooperation of the Indiana State Police. Superintendent Harold S. Zeis delegated responsibility for assistance in the project to Captain R. Max Branch of the Traffic Division. Arrangements for manpower and equipment required from the State Police were made by Captain Branch. Without this wholehearted support the experiment would not have been possible.[7]

Basically the experiment consisted of having six observers in four aircraft check the speed of a test car as it made 100 runs through the test area. The ground check used as a standard was made with a Speed-Watch with secondary checks being made with the speedometer of the test car and with a fifth wheel.[8] This design was intended to give six air checks against each ground standard or 600 air against 100 ground measurements. The Speed-Watch used for ground measurement was modified by increasing the distance between hoses to the distance between the white lines painted on the road, 660 feet or one eighth of a mile.[9] One hose was set at the leading edge of each of the two lines. This meant that the calibration on the face of the Speed-Watch, being based on a different distance, could not be used. Instead, readings from the Speed-Watch were recorded and processed exactly as were those made by hand by air observers. This method of ground measurement was chosen as the standard because it corresponded exactly to the air method except that the human elements of judgment and reaction time were eliminated. Protection of the validity of the standard against reading and recording errors was attempted by having two independent readings and recordings after every run which were checked for agreement prior to clearing of the watch.[10]

A decision was made to include the fifth wheel measurements for two purposes. It made it possible to determine how close to his intended speed the operator of the test car was able to drive and, together with the recorded speedometer readings, gave a rough check of the advantage to the motorist built into the system.

A section of limited access highway containing a test strip located near both Indiana University and the Indiana State Police Post at Bloomington

[7] In addition to Captain Branch, personnel from the Indiana State Police who participated were Capt. C. L. Melvin, Lt. E. R. St. John, F. Sgt. R. H. Myers' Sgt. G. S. Holt, Corp. L. E. Conway, Troopers C. H. Ferrell, P. H. Vogel, H. B. Rayborn, M. F. McKinney, James Robinson, E. W. Gordon, C. W. Epler, Radio Engineer G. M. Nutty and Mechanic W. R. Evans. Harry F. Van Dyke of the Indiana University campus police also assisted. The author is also indebted to his colleagues Robert F. Borkenstein, A. Robert Matt and Hillard J. Trubitt of the Department of Police Administration and Center for Police Training and to Professor Bernard I. Loft, Department of Health and Safety, School of Health, Physical Education and Recreation, Indiana University, and to one of Dr. Loft's graduate students, Mr. Otto H. Spilker.

[8] For information on the fifth wheel, see Easton, Report Number Six, Engineering Experiment Station, College of Engineering, University of Wisconsin, Ch. 2, p. 2 and publications of the Performance Measurements Company describing their Fifth Wheel, Model PM-1625.

[9] This modification did not introduce an error. The velocity of electric current is 186,000 miles per second. Therefore, the current travels one mile in 1/186,000 or 0.000,005,3 seconds. The length of electric cord used was 681 feet (21 more feet than the actual distance between lines was needed for connections) or 681/5280 or 0.13 miles. This made the time lag due to this length of cord 0.13 × 0.000,005,3 or 0.000,000,689 seconds. (Private communication to the author from Charles F. Pippen, Communications Section, Indiana State Police.) These times would also cancel. The modified Speed-Watch was furnished by the Traffic House, Marshall, Michigan.

[10] That this protection was effective is indicated by the fact that there was only one run (Run No. 94, Table One) in which there was agreement among all other readings which disagreed by more than one mile an hour with the ground standard. In all other runs, there was at least one independent observation in agreement with the ground standard or within one mile per hour.

around which a detour could easily be established was chosen as the experiment site. Troopers or university policemen were placed at all entrances to this highway section to eliminate all traffic except the test car. Since speeds in excess of 100 miles per hour were planned, this was a necessary safety precaution. The four aircraft used and their heights of operation were a Bell 47 G2 Helicopter at 500 feet, a Piper PA-18 Supercub at 1000 feet, a Piper PA-22 Tri-Pacer at 1500 feet, and a Piper PA-24 Apache[11] at 2000 feet. Both the Tri-Pacer and Apache carried two speed checkers, one experienced and one inexperienced. Each checker was equipped with a stop watch which had been certified to be accurate within twelve seconds in twenty-four hours. The watch in the Speed-Watch had been similarly checked.[12] The author and one of his colleagues maintained a radio watch throughout the entire experiment to assure that the only radio contact between participants was an announcement at the start of each run by the test car as to the run number and direction. This was necessary to prevent mixing up of run numbers by speed checkers.

At the beginning of the experiment, the driver of the test car was given the following instructions:

1. Do not decide until beginning a run the speed at which that run will be made. When the decision is reached, announce the intended speed to the recorder in the car.
2. Make a total of 100 runs through the test area, considering these as five groups of twenty.
3. Of each twenty:
   a. 19 should be at speeds between 55 and 110 mph with the great majority between 70 and 90 mph. These speeds should be constant over the measured distance.
   b. One of each 20, five in all, should be at changing speed. On four of these, slow up considerably after hitting the first tube. On the fifth, increase speed upon hitting the first tube.

Prior to the experiment, the speedometer of the test car had been checked against the Clayton Dynamometer[13] and the fifth wheel and found to be accurate in the 50–100 mph range.[14] In addition to the driver, the test car contained a recorder-radio operator and a man to read the fifth wheel.

Two difficulties were encountered in execution of the above design. The first was a malfunction of the Speed-Watch when tripped at high speeds. High speed impact rolled the tubes and jammed the mercury switches. Once recognized, this difficulty was quickly overcome by proper pegging of the tubes. The second problem was that one of the men recording speed in one of the aircraft or in the test car would occasionally miss a run. As a result, it was necessary to make 119 runs in order to get 99 complete sets of figures. When the experiment was ended, 100 sets were believed available, but inspection revealed that only 99 met the established criteria.

Discussion of Results

Table 1 is a summary of the basic data obtained in the experiment. As planned, 51 of the runs were in the 75–84 mph zone, the zone in which most of the arrests by this method are made. Table 2 shows the distribution of error for the entire experiment and for each of the air observers, as well as other data discussed below. The curves from these data approximate the normal distribution curve but with a slight negative skew. Note that with the exception of three recordings, the errors are confined to the range between plus and minus four miles per hour. This means that in 591 measurements, the maximum error was four miles per hour. Of the three errors in excess of four miles per hour, one was plus five and one plus six miles per hour. The third was minus thirteen miles per hour. The six mph error was made on the very first run by the least experienced of the experienced timers.

[11] This plane was borrowed from the Indiana State Highway Department. The state police plane of comparable size was undergoing a routine overhaul.

[12] These test records are in the files of the author.

[13] For descriptions of this device and its operation, see CLAYTON CHASSIS DYNAMOMETER, OPERATOR'S HANDBOOK and CLAYTON CHASSIS DYNAMOMETER, INSTRUCTION MANUAL, the Clayton Mfg. Co., El Monte, California.

[14] Calibration figures were as follows:

Dynamometer	Speedometer	Fifth Wheel	Speedometer
20	16	20	16
30	26	30	27
40	39	40	39
50	49	50	50
60	60	60	60
70	70	70	70
80	80	80	80
90	90	90	90

(Personal communication to the author from Lt. Charles O. Williams, Automotive Division, Indiana State Police.)

TABLE 1

Run Number	Intended Speed	Fifth Wheel		Helicopter	Piper Cub	Tri-pacer		Apache		Electric Timer
		High	Low			Old	New	Old	New	
1	85	87	85	90	86	83	84	84	86	84
2	75	78	77	75	76	75	76	73	75	75
3	90	92	91	90	91	90	91	90	91	90
4	80	82	81	80	81	78	80	78	67	80
5	90/75	90	76	78	78	78	80	80	78	78
6	70	71	71	70	70	69	70	69	69	69
7	87	90	87	88	90	86	90	86	90	86
8	77	79	78	76	78	76	78	77	76	77
9	80	81	80	80	80	78	80	78	80	81
10	92	93	92	93	91	90	91	90	91	91
11	95	—	—	93	95	93	97	91	95	95
12	72	72	71	70	72	70	70	71	70	71
13	87	88	87	88	86	86	88	84	86	88
14	74	75	75	76	75	72	75	73	75	73
15	85	86	85	86	86	84	84	84	88	84
16	92	93	91	93	90	90	91	91	91	91
17	85	86	85	86	86	84	84	84	84	84
18	76	77	77	75	77	75	76	75	77	76
19	85	86	85	86	86	84	84	84	86	84
20	70	71	71	70	71	69	70	70	70	69
21	95	95	95	93	95	91	95	93	95	93
22	77	78	77	77	76	75	76	77	76	75
23	76	77	77	76	77	75	75	77	75	76
24	90	92	90	90	91	90	90	88	90	91
25	100	102	99	100	100	100	102	102	97	100
26	83	84	84	84	83	81	81	81	83	81
27	70	72	71	70	70	68	69	69	70	69
28	82	83	82	81	81	81	80	81	83	81
29	72	72	72	71	72	71	72	72	72	71
30	102	105	102	100	102	100	102	100	102	102
31	72	73	72	75	75	71	72	72	69	71
32	87	88	88	86	86	86	86	84	86	86
33	95	97	96	93	97	93	93	93	91	95
34	77	78	77	78	77	76	77	76	77	76
35	90/60	90	62	71	70	69	70	71	71	70
36	55	56	55	55	55	54	54	54	55	55
37	82	83	83	81	81	81	81	81	81	81
38	90	94	92	90	93	90	90	90	90	90
39	72	73	72	72	72	71	72	70	71	71
40	87	88	87	88	88	86	86	84	88	86
41	77	77	77	78	77	76	75	75	78	76
42	85	86	85	86	86	84	88	84	82	84
43	76	78	77	77	77	75	76	76	77	75
44	95	96	95	93	95	95	97	93	93	93
45	75	76	75	75	76	73	73	75	75	75
46	82	83	82	81	81	80	83	81	81	83
47	85	87	86	83	84	84	86	86	84	83
48	78	79	78	78	78	77	78	76	77	77
49	77	78	77	76	76	75	75	76	75	75
50	85	86	86	84	84	83	84	86	86	84

TABLE 1—*Continued*

Run Number	Intended Speed	Fifth Wheel		Helicopter	Piper Cub	Tri-Pacer		Apache		Electric Timer
		High	Low			Old	New	Old	New	
51	76	77	—	78	76	75	77	75	75	75
52	65	66	66	65	66	64	65	65	65	63
53	95	96	95	93	97	95	97	95	95	95
54	60	61	60	60	60	59	62	60	60	59
55	90	91	90	90	91	90	88	90	90	90
56	77	78	78	76	76	76	77	76	76	76
57	81	82	81	81	80	78	78	80	83	80
58	73	74	74	73	72	72	72	72	72	72
59	70/80	83	70	76	77	75	75	76	76	75
60	71	72	71	69	72	70	70	70	69	69
61	83	84	83	84	83	81	81	83	83	84
62	90	92	90	90	91	88	88	90	91	90
63	85	87	86	86	86	84	84	84	86	84
64	76	77	76	75	76	75	76	76	75	75
65	82	84	82	83	83	81	81	83	83	81
66	75	76	76	76	75	73	75	75	75	75
67	80/65	80	66	70	69	69	68	69	70	69
68	70	71	70	69	70	69	69	69	69	69
69	95	97	95	97	95	93	93	95	95	95
70	74	75	75	73	75	73	75	72	73	72
71	83	84	84	83	83	83	83	84	84	83
72	79	80	79	78	80	77	78	78	78	77
73	80	81	80	80	81	78	78	78	80	80
74	76	77	77	77	76	75	76	75	76	75
75	100	102	101	102	104	100	100	100	100	100
76	81	82	82	81	81	80	81	80	80	80
77	57	59	57	60	57	57	57	58	57	57
78	72	73	72	71	72	71	71	71	70	70
79	87	89	87	86	88	86	86	86	88	86
80	77	78	78	78	78	76	76	76	77	76
81	84	85	85	84	84	84	84	83	83	83
82	75	76	75	75	76	75	76	75	75	75
83	86	88	87	84	88	86	86	86	86	86
84	75	76	75	75	75	75	75	75	75	75
85	88	90	89	90	90	88	88	88	90	88
86	85	86	85	88	86	84	84	84	86	84
87	85/60	85	62	70	71	69	69	70	69	70
88	50	51	51	50	50	50	50	50	50	50
89	95	96	96	97	95	93	93	93	97	93
90	86	88	88	90	86	84	86	86	86	86
91	79	80	80	78	78	77	78	77	77	78
92	76	78	77	76	77	75	77	75	75	76
93	80	81	80	83	81	80	81	78	78	78
94	80	81	81	81	80	80	80	80	80	78
95	92	93	92	93	93	90	91	93	90	91
96	77	78	77	76	77	76	76	75	76	76
97	79	79	79	77	78	77	78	78	78	77
98	77	78	77	76	77	77	77	76	76	76
99	90	91	91	91	91	88	88	90	90	90

TABLE 2

Aircraft Unit	Number of Clock Checks	Absolute Deviation in Miles per Hour												Sigma			Error		
		−13	−4	−3	−2	−1	00	+1	+2	+3	+4	+5	+6	SD*	2SD	3SD	Avg	Mean	Std
Helicopter	99	—	—	—	6	5	37	19	21	5	4	1	1	1.52	3.04	4.56	1.21	0.87	0.15
Piper Cub	99	—	—	—	2	3	24	35	26	6	3	—	—	1.15	2.30	3.45	1.25	1.11	0.12
Tri-Pacer Experienced Timer	99	—	—	3	14	17	55	7	3	—	—	—	—	1.02	2.04	3.06	0.68	−0.41	0.10
Tri-Pacer Inexperienced	99	—	—	1	7	9	42	24	9	4	3	—	—	1.33	2.66	3.99	0.93	0.40	0.13
Apache with Experienced	99	—	2	2	8	10	52	16	8	1	—	—	—	1.23	2.46	3.69	0.76	−0.05	0.12
Apache Inexperienced	99	1	1	1	4	10	42	19	17	1	3	—	—	1.89	3.78	5.67	1.07	0.30	0.19
All Runs on All Timers	594	1	3	7	41	54	252	120	84	17	13	1	1	1.48	2.96	4.44	0.98	0.37	0.06
75–84 MPH†	306	1	—	5	16	29	127	68	46	9	3	1	1	1.51	3.02	4.53	0.98	0.40	0.09

* SD = Standard Deviation.

† All runs on all timers between 75–84 MPH inclusive.

The five mph error was made by the same timer on the 93d run. The thirteen mile per hour error was made on the fourth run by one of the inexperienced timers. It was detected at the time made by a non-official observer in the same plane and reported to the author prior to compilation and analysis of the data. The mistake was a one second misreading of the watch, which was unfamiliar to the timer.

Of particular significance would seem to be the data on standard deviation and on average, mean and standard error in Table 2. Standard deviation is a figure which establishes a plus and minus range within which approximately 65 per cent of cases will fall for a curve with normal distribution. The standard deviation is normally referred to as *sigma*. Approximately 95 per cent of cases will fall within two *sigma* and substantially all cases within three *sigma* with normal distribution. Even in the most carefully controlled scientific measurement, there will be infrequent "flyers" which will fall outside this range. Table 3 makes it obvious that the standard deviation data from Table 2 give curves when plotted which approach the normal in extremes but which tend to have a disproportionate number of readings close to the zero deviation axis.

Average error is the absolute value of the error which may be expected on an average run. Mean error is the mean of all errors, balancing the positive against the negative. When the mean error is positive, the distribution of error in the curve for which it is plotted will have a negative skew. When the mean error is negative, the curve will have a positive skew. The standard error of Table 2 is actually a determination of the range within which the mean error figures will vary. It is calculated by dividing the standard deviation for each data group by the square root of the number of measurements within that group. This figure makes it possible for us to say that for speed measurement from aircraft the mean error for an infinite number of measurements would be 0.37 ± 0.06 mph. In other words, in 65 cases out of one hundred the true mean error is between 0.31 and 0.43 mph.[15]

TABLE 3

	Sigma	2 Sigma	3 Sigma
Normal distribution	68.0%	95.0%	99.7%
All aircraft	71.9%	92.7%	99.5%
Helicopter	67.1%	94.0%	98.0%
SuperCub	62.6%	95.0%	97.0%
TriPacer (Experienced)	79.8%	97.0%	100.0%
TriPacer (Inexperienced)	75.8%	91.9%	97.0%
Apache (Experienced)	78.8%	95.0%	98.0%
Apache (Inexperienced)	71.8%	97.0%	99.0%

[15] Assistance in the statistical treatment of data was obtained from the Research Computing Center of

TABLE 4

Speed Range MPH	Number of Clock Checks	Absolute Deviation in Miles per Hour												Sigma			Error		
		−13	−4	−3	−2	−1	00	+1	+2	+3	+4	+5	+6	SD*	2SD	3SD	Avg	Mean	Std
50–54	6	—	—	—	—	—	6	—	—	—	—	—	—	0	0	0	0	0	0.00
55–59	18	—	—	—	—	3	8	5	—	2	—	—	—	1.15	2.30	3.45	0.78	0.44	0.27
60–64	6	—	—	—	—	—	—	1	4	1	—	—	—	0.63	1.26	1.89	2.00	2.00	0.26
65–69	36	—	—	—	—	2	16	16	1	1	—	—	—	0.76	1.52	2.28	0.64	0.53	0.13
70–74	60	—	—	—	1	10	18	22	4	3	2	—	—	1.23	2.46	3.69	0.98	0.58	0.16
75–79	174	—	—	—	4	19	71	53	21	5	—	1	—	1.07	2.14	3.21	0.82	0.51	0.08
80–84	132	1	—	5	12	10	56	15	25	4	3	—	1	1.94	3.88	5.82	1.19	0.25	0.17
85–89	48	—	1	—	7	—	26	—	10	—	10	—	—	1.71	3.42	5.13	1.12	0.38	0.25
90–94	72	—	—	1	6	10	32	8	11	1	3		—	1.42	2.84	4.26	0.83	0.28	0.17
95–99	24	—	2	—	8	—	9	—	5	—	—		—	1.82	3.64	5.46	1.42	−0.58	0.37
100–104	18	—	—	1	3	—	10	—	3	—	1		—	1.70	3.40	5.10	1.16	0.06	0.40
75–84	306	1	—	5	16	29	127	68	46	9	3	1	1	1.51	3.02	4.53	0.98	0.40	0.09

* SD = Standard Deviation.

Table 4 shows the distribution of error for the following speed ranges: 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84, 85–89, 90–94, 95–99, 100–104 and 75–84. The multimodal curves in the ranges above eighty miles per hour can be explained by the fact that in this range a decrease of a tenth of a second in time makes an actual increase of at least 1½ miles per hour in speed. As would be expected, this tendency is more pronounced at higher speeds, becoming absolute for all readings of 93 miles per hour and above. This arises from the fact that the anticipated and casual errors in terms of tenths of a second remain in the same absolute range while total time for test runs decreases by nearly 50 per cent from the lowest to the highest speeds in the experiment. This means an increase in relative error at higher speeds.

A comparison was also made of Speed-Watch readings with the average direct readings from the test car speedometer and the fifth wheel. The following variations were noted: +1 mph, 4 runs; 0.0, 9 runs; −1.0, 41 runs; −2.0, 32 runs; and −3.0, 6 runs.[16] Accepting agreement between car speedometer and fifth wheel as indicating correct speed, this gives a mean error of −1.29 miles per hour for the Speed-Watch which compares favorably with the calculated advantage to the motorist of the system.[17]

Attention was also paid to the deviation of actual speed as registered by the fifth wheel from announced intended speed. The following deviations were noted: +3.0 mph, 1 run; +2.5, 1 run; +2.0, 1 run; +1.5, 14 runs; +1.0, 31 runs; +0.5, 38 runs; 0.0, 5 runs; and −0.5, 1 run. The mean error is 0.85 miles per hour.

Figure 3 deals with the learning factor involved in checking speed by this method. Although the data are not conclusive, these curves and similar ones for other observers, emphasize that the observers with the greatest amount of recent experience turned in markedly more accurate records than did those with less or older experience and with no experience.[18]

Indiana University. Much patient counseling was also given by Professor Arnold Binder of the Indiana University Department of Psychology.

16 Of the 99 runs, five were at variable speeds and readings were not obtained for an additional two. This leaves 92 runs on which data are available.

17 See the discussion on page 215 above of the advantage to the motorist built into the system.

18 There were completely inexperienced observers in both the Apache and TriPacer. One of these had never been aloft in any aircraft previously, and the other had never been aloft in a light plane. The observer in the helicopter had been given orientation in airspeed checking but had done very little actual checking. His most recent experience was one month old. The experienced observer in the Apache had three years of experience with the system but had not done active checking within the previous three months. The experienced observer in the TriPacer had six months of experience with the system and had been actively checking right up through the previous day as had the observer in the SuperCub, who had three months of active experience with the system.

(Private communication to the author from Sgt. Gilbert Holt, Air Section, Indiana State Police.)

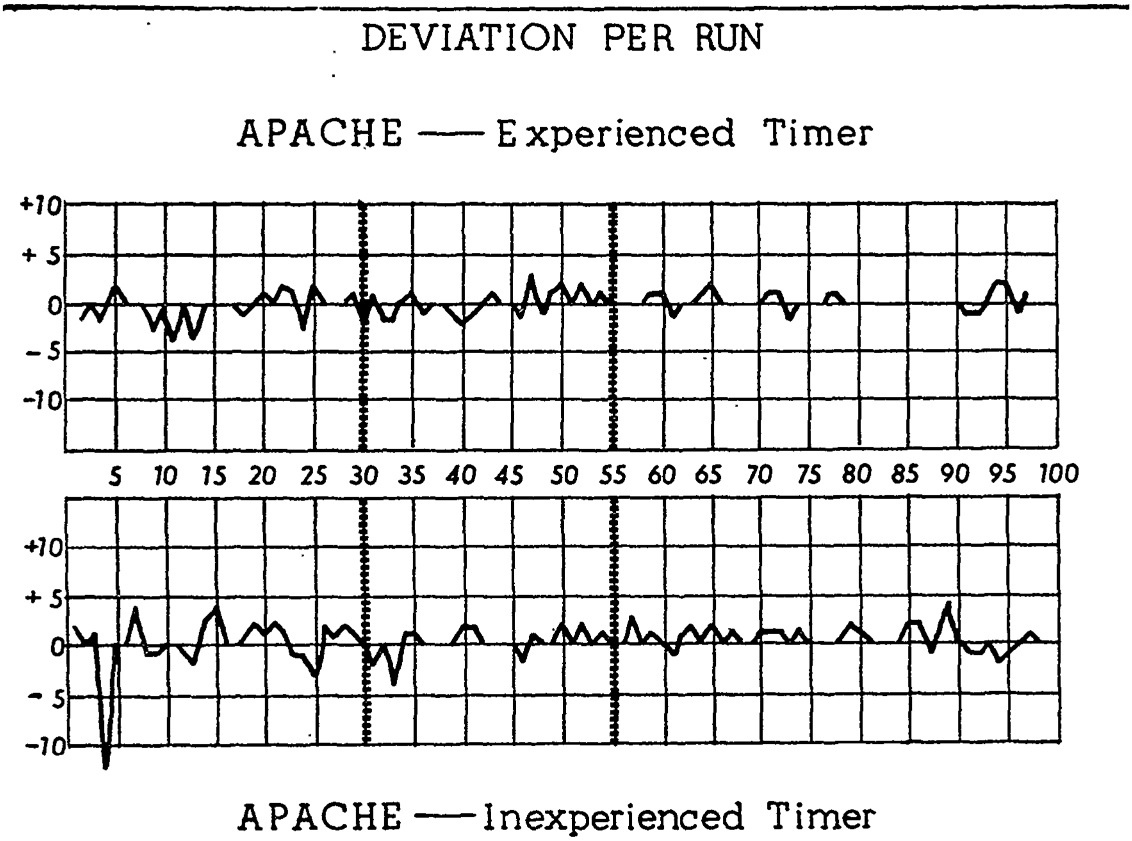

Figure 3
Deviation Per Run
The top chart shows errors in speed determination made by the experienced timer in the Apache; the lower chart, by the inexperienced timer in the same aircraft. The experienced timer's record is appreciably better, but the inexperienced timer shows improvement as the observations progress. The dotted vertical lines indicate breaks for rest periods. No attempt has been made to evaluate these records for exhaustion effects.

Conclusions

Results from this experiment justify the assertion that measurement of motor vehicle ground speed from aircraft is reliable. Despite the fact that the timing of split seconds is involved, the human error in the system used is very small. Exactly correct answers will be obtained in about 43 per cent of the cases. Of the remaining 57 per cent, negative errors will be made in about 17 per cent of the cases. In that 40 per cent of the cases in which positive errors will be made, the average error will be 1.70 mph.[19] This must be set off against the advantage to the motorist of 1.2 mph built into the system. It should also be remembered that the work of inexperienced observers is included in these figures. The highest positive error in 596 checks was 6 miles per hour. Since the violation charged is exceeding the speed limit by at least ten miles per hour in at least 98 per cent of the cases,[20] these possible errors will not cause mis-

[19] This figure is easily calculated from data in Table 2. It does not appear in any of the tables.

[20] The actual fact on which reliance is being placed is that 98 percent of the cases involve charges of speeds of 75 mph and above. This would be a minimum of ten miles over the highest prima facie legal limit for Indiana. The author has a strong suspicion that the majority of the cases where the speed charged was lower than 75 mph involved restricted speed zones where the charged speed was at least ten mph over the absolute legal limit.

carriages of justice. On the whole, the method seems to be far less susceptible to human error with the observer sitting safely in the air at his vantage point than with an observer driving an automobile through all of the hazards of modern traffic, as is the case in the common method using the police cruiser speedometer.

Results from this experiment also justify the assertion that even this excellent record can be improved by using only operators who are experienced or who have been trained in a short but intensive training program. A one day school emphasizing the rules to be followed in air speed check procedures and the reasons behind them, practice in reading stop watches which have been run for differing intervals, and practice in recording such readings should raise the standard of performance considerably.

Factors not explored in this experiment which might also be studied in attempts at improvement include altitude, position of the aircraft in relation to the test strip at the time the run is made, and the effect of fatigue on the observer. Data on these variables should be recorded and analyzed in any independent check of this experiment.