Laboratory Evaluation of PAS III Sensor with New Pump Design

Michael X. Cammisa
Susan A. Ferguson
JoAnn K. Wells

March 1996

INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

1005 N. GLEBE RD. ARLINGTON, VA 22201-4751
PHONE 703/247-1500 FAX 703/247-1678
website http://www.highwaysafety.org

ABSTRACT

The PAS III passive alcohol sensor was evaluated to determine its effectiveness as a screening device to assist law enforcement officers in identifying alcohol-impaired drivers. Under laboratory conditions, the PAS III achieved its best discrimination of drinking subjects with high blood alcohol concentrations (BACs) of 0.10 percent and low BACs of 0.02 percent when the sensor was held at a distance of 5 inches from the subject. At this distance, the sensor would be expected to correctly identify 95 percent of drinking subjects with BACs of 0.10 percent, and incorrectly identify 1 percent of subjects with BACs of 0.02 percent as having a 0.10 percent BAC. The new design of the PAS III results in improved performance at further test distances compared with an earlier design. The PAS III is expected to correctly identify more subjects having a 0.10 percent BAC at a 10 inch test distance than the previous design did at 5 inches, with a reduction in the percentage of lower BAC subjects misidentified as having a high BAC. Because the BAC threshold varies by jurisdiction and class of driver (i.e., adult drivers, young drivers, and commercial drivers), expected detection rates for the PAS III were also calculated for BACs of 0.08, 0.05, and 0.02 percent. Passive alcohol sensors may be particularly important in identifying drivers at these lower BACs because behavioral evidence of impairment may not be present. A second study indicated that these results can be obtained under laboratory conditions even with relatively inexperienced sensor operators.

INTRODUCTION

Passive alcohol sensors are devices designed to assist law enforcement officers to quickly and reliably identify alcohol-impaired drivers who are stopped for traffic violations at roadside checkpoints, or at the scene of a crash. The passive alcohol sensor samples the air containing the exhaled breath of the driver and provides the police with an immediate indication of the driver's approximate blood alcohol concentration (BAC). A sensor will be most useful as a screening device if it accurately identifies drivers that should be detained for further testing and holds to a minimum the number of drivers incorrectly identified as having BACs that warrant further testing.

All but two states have per se laws that define driving with a BAC above a proscribed threshold as a crime. Although the threshold in most states is 0.10 percent, 13 states have lowered the per se threshold to 0.08 percent, and 33 states and the District of Columbia have established very low or zero BAC limits for young drivers. Federal law requires that a commercial driver having a BAC of 0.02 percent be taken out of service for 24 hours, with the penalty for a 0.04 percent BAC per se violation being disqualification. Although a 0.05 percent BAC is a point at which nearly all important components of driver performance become impaired (Moskowitz and Robinson, 1987), visible signs of driver impairment may be less apparent at these lower BACs. An effective passive alcohol sensor could be very useful to police officers in making an appropriate initial assessment of the need for further testing.

A previous study examined the performance of two passive alcohol sensors (the National Patent Analytical Systems (NPAS) sensor and the Life-Loc sensor) in detecting BACs above and below specified thresholds (Lestina and Lund, 1992). The study concluded that the sensors performed reliably enough when held five to six inches from the subject to be used as screening devices to detect drivers with BACs at or above 0.10 percent. At that distance, the Life-Loc sensor was expected to detect 80 percent of drivers with a BAC of 0.10 percent while incorrectly identifying 12 percent of drivers with a BAC of 0.02 percent as having a high BAC. The NPAS sensor was expected to detect 75 percent of drivers having a BAC of 0.10 percent and to incorrectly identify about 19 percent of drivers with BACs of 0.02 percent. At the time the study was conducted, 44 states and the District of Columbia had per se BAC laws in effect, and all but three of these had established thresholds of 0.10 percent.

The design of the NPAS sensor, which is built into a standard police flashlight, has since been modified to include a stronger pump for drawing the air sample, which may affect its performance. This sensor, which is manufactured by Public Service Technologies, Inc., was renamed the PAS III. In addition to the stronger pump, new indicator lamps have been installed. The older NPAS sensor display has 10 rectangular LED lamps of the same size — three green, four yellow, and three red — to indicate the alcohol concentration in the air sample, with the first of the three green lamps always illuminated whenever the unit is on. The PAS III has nine rectangular LED lamps — two green, four yellow, and three red — for indicating the air sample's alcohol concentration and a smaller green lamp at the bottom of the display that is illuminated whenever the power to the unit is on. (See Figure 1.)

This report presents the results of two laboratory studies that were conducted to test the effectiveness of the new PAS III design as a screening device for detecting breath alcohol in drivers with different BACs. The first study was designed to replicate as closely as possible the procedures used in previous performance evaluations of the NPAS sensor (Lestina and Lund, 1992). The second study, which was limited in scope, was undertaken to provide a preliminary indication of whether different, relatively inexperienced PAS III operators would obtain consistent results over a range of BACs. To be most useful in the field, the sensor should provide reliable results when used by a variety of operators with different levels of experience and training.

METHODS

Laboratory Response Testing

Four drinking subjects, two male and two female, and one experimenter operating the PAS III sensors, which had been calibrated by the manufacturer, participated in the performance test. Four sensors were used in the study. At the beginning of the test, the subjects were tested with a Lion SD-2 Alcolmeter, a small hand-held unit that measures a subject's BAC from a 1 ml sample of deep lung breath blown through a tube. The Alcolmeter is considered to estimate BAC accurately within ± 10 percent (Lion Laboratories, Ltd., 1987) and is on the National Highway Traffic Safety Administration's qualified products list for evidential breath test devices. No alcohol was detected for each subject prior to the commencement of the study.

Subjects were given their choice of mixed drinks. The four subjects drank 6-12 ounces of 80 proof alcohol in a 39-83 minute period to reach a BAC of approximately 0.10 percent. All subjects were tested at 15 minute intervals with an Alcolmeter to determine their BACs. When two consecutive Alcolmeter readings showed no further increase in BAC, testing of the PAS III began. Although the goal was to have each subject reach a BAC of 0.10 percent, the maximum measured BACs for the four subjects prior to the first PAS III measurement were between 0.085 and 0.117 percent due to the different absorption rates for the subjects and a pre-set maximum number of drinks of four (approximately 8 ounces of alcohol) for the female subjects and six (approximately 12 ounces of alcohol) for the male subjects.

Figure 1
PAS III Passive Alcohol Sensor

Each subject was tested with each PAS III sensor at each of three test distances. The test distances (5 inches, 7.5 inches, and 10 inches) match those used in Lestina and Lund (1992) and include the manufacturer's recommended range of 5 to 7 inches (Public Service Technologies, 1995). The sensor was positioned by the experimenter at the measured distance with the inlet directly in front of the subject and at the same height as the subject's mouth. The subjects were asked to recite their names and addresses while the sampling of the air was conducted. The pump runs for a period of 5 seconds to draw in the air sample. Once the sampling was complete and the reading stabilized, the maximum number of LED bars that were observed for the sample was recorded, and the process was repeated with the next sensor at that distance. This procedure was repeated at each of the three distances for each sensor.

The subjects' BACs were monitored at 15 to 20 minute intervals using an Alcolmeter breath tester. The test was repeated as the subjects' BACs dropped to approximately 0.08 percent, 0.06 percent, and 0.04 percent, and concluded when all of the subjects had BACs of approximately 0.02 percent. The order in which the four sensors were tested during each set of tests (one subject at a given BAC at all three distances) was alternated in a Latin Square fashion. Before and after each set of tests, the time and the subject's BAC as measured by the Alcolmeter were recorded.

Analyses of Laboratory Tests

The test results were analyzed to estimate the ability of the sensors to detect individuals with BACs of 0.02, 0.05, 0.08, 0.10, and 0.15 percent at each of the three test distances. A regression analysis was conducted to evaluate the relative contributions of BAC, subject, sensor, and distance on the variability of the sensor readings. These results were compared with the results of the Lestina and Lund (1992) study.

To assess the ability of the sensors to correctly identify drivers in violation of specific BAC thresholds, a simple regression analysis was performed with the sensor reading as the dependent variable and subject BAC as the independent variable of the form: Number of Bars = $\alpha + \beta$(BAC), where number of bars is the sensor reading (number of LED bars that light up) for a given observation, α is the intercept and β the slope of the regression line, and BAC is the average of the beginning and ending Alcolmeter reading for each observation.

Separate regression analyses were performed for each of the three distances tested. During the testing, 80 observations were collected at each distance. However, when held at a distance of 5 inches the PAS III tended to reach its upper limit (three red bars) for subjects with a BAC greater than 0.08 percent. So, to avoid underestimating the slope of the regression line, only the 56 observations taken for BACs less than or equal to 0.08 percent were used at the 5 inch distance.

The expected percentages of people that the sensor would identify as having BACs that would warrant further testing were calculated for selected sensor and BAC thresholds. To be effective in a situation in which the per se BAC threshold is 0.08 or 0.10 percent, the sensor should not lead officers to detain a large number of drivers well below the per se threshold or to miss a large number of drivers above the threshold. The best performance would achieve an acceptable balance.

Using the regression equations, the expected sensor readings and their standard deviations were estimated for BACs of 0.02, 0.05, 0.08, 0.10, and 0.15 percent to determine the expected proportion of drivers detected at all sensor readings from a minimum of one green bar to the maximum sensor reading of three red bars. Due to the redesign of the indicator display, two green bars in the current study is equivalent to three green in Lestina and Lund (1992).

Using the least squares general linear models of SAS-GLM (SAS Institute, 1990), multiple linear regression analyses were performed to test the relative contribution of BAC and several other factors on the variability of the sensor readings. The first of these models includes BAC, subject, sensor, and test distance as well as all two-way interactions. A second model controls for distance. The dependent variable in both models was the sensor reading in number of bars. BAC and distance were entered as covariates in the models, while sensor and subject were class variables. As in the analysis of the BAC-PAS reading relationship, those observations at the 5 inch distance with BACs greater than 0.08 percent were eliminated from the regression.

The variability in sensor readings attributable to each predictor variable was expressed as the proportion of the total sum of squared deviations accounted for by that predictor in the regression model. The variability (sum of squares) was partitioned among the predictors using the Type I solution.

Operator Tests

In addition to comparing the performance of the new and old designs of the passive alcohol sensor, a limited study was conducted to examine the effect of using different, relatively inexperienced testers on the PAS III readings. For this study, a laboratory test was performed with two drinking subjects, one male and one female, and four experimenters (two male and two female), only one of which had previous experience operating the PAS III sensors.

The three novice sensor operators were given brief operating instructions by the experienced operator, and spent about 10 minutes working with the sensor to get a feel for how the controls worked. The testing procedure was the same as for the performance test except that each test was conducted by each of the four operators using only two PAS III sensors on each subject at each BAC and distance. An initial BAC measurement was obtained for the subject using the Alcolmeter, and one operator then recorded the PAS III reading for each sensor at each of the three test distances. Upon completion of this sequence, an interim BAC measurement was obtained and recorded along with the time. This BAC represented the final BAC for that operator and the beginning BAC for the next operator.

Interim BAC measurements were taken for the subjects because the subjects' BAC can be expected to change during the time required for the four PAS III operators to obtain all of the necessary readings. After the interim reading was taken, the next operator would take PAS III readings on the same subject at each of the three test distances until all four operators had completed the required tests for that subject at that BAC.

Although it was intended that each subject would reach a BAC of 0.10 percent prior to the tests, this BAC was not reached for either subject. Alcohol consumption was stopped after four drinks (approximately 8 ounces of alcohol) for the female subject and six drinks (approximately 12 ounces of alcohol) for the male subject. Thus, the initial set of measurements for this test began when the female subject had reached a BAC of 0.05 percent and the male subject reached a BAC of 0.09 percent.

RESULTS

The percentages of drivers expected to be detected by the PAS III at three distances and five BAC thresholds are shown in Table 1. Like the previous design NPAS sensor, the best performance for the PAS III in identifying drivers with BACs of 0.10 percent while minimizing erroneous low BAC detections would be expected when the sensor is held closest to the driver. Using a sensor reading of two red bars at the minimum tested distance of 5 inches, the PAS III would be expected to detect 95 percent of drivers with a BAC of 0.10 percent, while incorrectly identifying 1 percent of drivers with BACs of 0.02 and 21 percent of drivers with BACs of 0.05 percent as exceeding the 0.10 percent BAC threshold. This is an improvement over the best NPAS performance which was obtained at a 5-inch test distance and a sensor reading of one yellow bar. At this reading and distance combination, the NPAS would be expected to detect about 75 percent of drivers with a BAC of 0.10 percent while incorrectly identifying 19 percent of drivers with BACs of 0.02 percent and 40 percent of drivers with BACs for 0.05 percent (Lestina and Lund, 1992). The results of this study also indicate that the new PAS III design will improve the sensor's performance when held at distances further from the driver compared with the best NPAS performance at 5 inches which may be easier for officers to attain in the field. Using a sensor reading of three yellow bars at the maximum tested distance of 10 inches, the PAS III would be expected to identify 82 percent of drivers with a BAC of 0.10 percent, while incorrectly identifying 15 percent of drivers with BACs of 0.02 percent and 38 percent of drivers with BACs of 0.05 percent as exceeding the 0.10 percent BAC threshold.

Table 1
Laboratory Performance of PAS III at Various Thresholds

		Expected Percent Detection at BAC:				
Distance	**Threshold:**	**0.02**	**0.05**	**0.08**	**0.1**	**0.15**
5.0 Inches	1 green	100	100	100	100	100
	2 green	100	100	100	100	100
	1 yellow	98	100	100	100	100
	2 yellow	89	100	100	100	100
	3 yellow	64	97	100	100	100
	4 yellow	30	84	99	100	100
	1 red	8	54	94	99	100
	2 red	1	21	76	95	100
	3 red	--	4	44	79	100
7.5 Inches	1 green	99	100	100	100	100
	2 green	95	99	100	100	100
	1 yellow	85	96	99	100	100
	2 yellow	67	88	97	99	100
	3 yellow	44	71	90	96	100
	4 yellow	23	48	75	87	99
	1 red	9	26	53	70	95
	2 red	3	11	30	48	86
	3 red	1	3	13	26	70
10 Inches	1 green	80	95	99	100	100
	2 green	65	87	97	99	100
	1 yellow	46	74	93	97	100
	2 yellow	28	57	82	92	99
	3 yellow	15	38	67	82	98
	4 yellow	6	22	48	67	95
	1 red	2	10	30	49	88
	2 red	1	4	16	31	76
	3 red	--	1	7	16	60

Selecting different sensor readings and distances can greatly affect the number of drivers detected at each BAC. At the optimal reading/distance criterion of two red bars and 5 inches for the 0.10 BAC threshold, only 76 percent of drivers at 0.08 percent would be detected. In an enforcement situation where it is desired to detain drivers with a BAC of 0.08 percent, the detection rate can be increased to 94 percent by adopting a criterion of one red bar at 5 inches. However, this criterion would also incorrectly identify more low BAC drivers as exceeding the 0.08 percent BAC threshold (8 percent of drivers with BACs of 0.02 percent and 54 percent of drivers with BACs of 0.05 percent). For detecting very low BAC drivers, holding the sensor at 7.5 inches or less and using a sensor reading of one green bar would identify virtually all such drivers.

The total sum of squared deviations in sensor readings and the percentage accounted for by BAC, subject, sensor, and distance variables, and their two-way interactions are shown for both the PAS III and the NPAS in Table 2. There is little difference between the old and new designs in this model. BAC accounts for most (22 percent for the PAS III, 21 percent for the NPAS) of the variation in the readings. For the PAS III, distance effects explain 21 percent of the variation and subject variability accounts for 19 percent, compared with 19 percent and 18 percent for distance and subject, respectively, for the NPAS sensor. None of the other sources tested in this regression model account for more than about 4 percent of the variation (including the variation contributed by the sensor) for either sensor design.

Table 2
Percent of Variation in Sensor Readings Explained by Selected Factors Comparison of NPAS and PAS III Designs

Source of Variation	NPAS		PAS III	
	Sum of Squared Deviations	Percent of Total Variation	Sum of Squared Deviations	Percent of Total Variation
Model	2161	73	748	69
BAC	612	21	237	22
Subject	530	18	204	19
Sensor	83	3	20	2
Distance	577	19	233	21
BAC x Distance	46	2	0	0
BAC x Subject	111	4	18	2
BAC x Sensor	32	1	4	0
Subject x Sensor	45	2	4	0
Subject x Distance	74	2	23	2
Sensor x Distance	49	2	4	0
Total	2960	—	1084	—

The distributions of variation explained when controlling for distance are shown in Table 3. BAC accounted for more of the PAS reading variability at 5 inches than at the other distances. Subject variability ranged from 17 percent to 26 percent of the total, and each of the other sources examined in this model accounted for no more than 5 percent or less of the variation.

When compared with the earlier NPAS design, the percentage contribution of BAC to the sensor reading for the PAS III was greater at all test distances (see Table 4), but the effects of other factors decreased or remained the same.

Table 3
Percent Variation in PAS III Readings Explained By BAC, Sensor, and Subject, at Each Test Distance

Source of Variation	5 Inches		7.5 Inches		10 Inches	
	Variation	Percent Total	Variation	Percent Total	Variation	Percent Total
Total	123		314		502	
Model	90 *	73	213 *	68	344 *	69
BAC	58 *	47	100 *	32	171 *	34
Subject	21 *	17	72 *	23	131 *	26
Sensor	4	3	16 *	5	11	2
BAC x Subject	4	3	13	4	12	2
BAC x Sensor	2	2	1	0	7	1
Subject x Sensor	1	1	12	4	12	2

*Statistically significant, $p<0.05$

Table 4
Percent Variation in Sensor Readings Explained by Selected Factors at Each Test Distance Comparison of NPAS and PAS III Designs

Source of Variation	5 Inches		7.5 Inches		10 Inches	
	NPAS	PAS III	NPAS	PAS III	NPAS	PAS III
Model	74	73	70	68	63	69
BAC	35	47	21	32	21	34
Subject	24	17	26	23	26	26
Sensor	5	3	7	5	5	2
BAC x Subject	4	3	9	4	5	2
BAC x Sensor	3	2	2	0	2	1
Subject x Sensor	3	1	4	4	4	2

* Statistically significant, $p<0.05$

Analysis of Variation Due to Tester

Table 5 shows the total sum of squared deviations in the PAS III readings and the percentage accounted for by each variable from the regression model that includes tester as a variable in addition to BAC, subject, sensor, and distance and all two-way interactions. BAC (39 percent) and distance (23 percent) account for most of the variation in the readings. The percentage of the variability in the PAS III readings accounted for by the tester is approximately 1 percent and is not statistically significant. These findings indicate that the effect of different PAS III operators on the sensor readings are negligible under laboratory conditions where the distance that the sensor was held from the subject was strictly controlled.

Table 5
Percent Variation in PAS Readings Explained
By BAC, Sensor, and Subject, Distance and Tester

Source of Variation	Sum of Squared Deviations	Percent of Total Variation
Total	691	
Model	503	73
BAC	272	39
Subject	19	3
Sensor	9	1
Distance	159	23
Tester	8	1
BAC x Distance	10	1
BAC x Subject	0	0
BAC x Sensor	0	0
BAC x Tester	2	0
Subject x Sensor	1	0
Subject x Distance	2	0
Subject x Tester	8	1
Sensor x Distance	2	0
Sensor x Tester	8	1
Distance x Tester	2	0

*Statistically significant, $p<0.05$

DISCUSSION

Passive alcohol sensors used as screening devices by law enforcement officers in the field have been shown to increase the detection rates of alcohol impaired drivers when the BAC threshold is 0.10 percent (Ferguson, Wells, and Lund, 1995; Kiger, Lestina, and Lund, 1993; Jones and Lund, 1985). The results of this evaluation of the PAS III indicate that this new sensor design can identify 95 percent of drivers with BACs of 0.10 percent, while keeping misidentification of low BAC drivers to a minimum, when it is held at a distance of 5 inches from the subject.

Officers using the previous design of the PAS III, the NPAS, often complained that the recommended distance of 5 to 6 inches was too close to the driver to be easily achieved in field use (Ferguson, Wells, and Lund, 1995). For detecting 0.10 percent BAC drivers, the PAS III achieved a higher level of performance at 10 inches than the best NPAS performance, which occurred at a 5-inch test distance (Lestina and Lund, 1992). The results of this study indicate that the PAS III sensor held at a 10-inch distance would be expected to correctly identify a higher percentage of drivers with 0.10 percent BACs (82 percent versus 75 percent) while incorrectly identifying fewer drivers with 0.02 percent BACs as having a 0.10 percent BAC (15 percent versus 19 percent) than the NPAS sensor held at a distance of 5 inches. This indicates that the PAS III would achieve acceptable performance levels in situations where the officer is unable to hold the sensor as close as 5 inches to the driver being tested. However, at distances further from the driver, wind may become a factor in the field.

Passive alcohol sensors may be particularly advantageous in field use when BAC thresholds are lower than 0.10 percent and behavioral evidence of impairment is less obvious to officers. The results of this laboratory study indicate that the new sensor can be used to reliably identify virtually all drivers with very low BACs. Correctly detecting most drivers at 0.08 percent is also possible but at the expense of also misidentifying a higher proportion of lower BAC drivers as exceeding the threshold. Officers in 0.08 BAC threshold states would need to decide whether to retain the optimal distance/reading criterion for detecting 0.10 BAC drivers and risk missing drivers between 0.08 and 0.10, or to adopt a relaxed criterion that maximizes 0.08 idenfication at the expense of unnecessarily detaining lower BAC drivers. Such drivers would be unlikely to be subject to arrest, although knowledge that the police can reliably detect them as having consumed alcohol may deter them from driving after drinking in the future.

Because the results of this study comparing the old and new sensor designs were obtained with a very experienced sensor operator, a small pilot study was performed to examine the effect of different, relatively untrained, operators on sensor readings. It is crucial that the PAS III performance not be widely different with different and inexperienced operators; conditions which can be expected if used in sobriety checkpoints, for example. The results of this rather limited study suggest that operator differences under laboratory conditions may be negligible in that the PAS III results were fairly consistent across all operators in this study. Although this indicates that operation of the PAS III can be taught fairly readily, the manner in which officers use the sensor and the behavior of stopped drivers may differ in the field, affecting the sensor's performance. For example, to get a good sample of the exhaled breath of the driver, the officer must activate the sensor's pump while the driver is speaking. The ability of the officer to keep the driver speaking during the pump's 5-second sample time will affect the quality of the reading. The amount of breath exhaled by the driver while speaking and the orientation of the driver's mouth to the sensor inlet would also be expected to influence the sensor reading. Because the distance the officer is able to hold the sensor from the driver and the BAC threshhold for different classes of drivers will vary in the field, officers must be careful to select a sensor reading criterion appropriate for the prevailing distance and BAC threshold to maximize sensor performance. Field tests of the PAS III where distance and wind conditions may not be well controlled are needed to evaluate the performance of these sensors in conjunction with the officer's judgment as a tool for identifying drivers for further testing.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Charles Farmer of the Institute for his help with the statistical analysis, and Sharon Rasmussen for editorial assistance.

REFERENCES

Ferguson, Susan A., Wells, JoAnn K., and Lund, Adrian K. (1995). The role of passive alcohol sensors in detecting alcohol-impaired drivers at sobriety checkpoints. *Alcohol, Drugs and Driving* 11:23-30.

Jones, I.S. and Lund, Adrian K. 1985. Detection of alcohol impaired drivers using a passive alcohol sensor. *Journal of Police Science Administration* 145:153-160.

Kiger, Steven M., Lestina, Diane C., and Lund, Adrian K. 1993. Passive alcohol sensors in law enforcement screening for alcohol-impaired drivers. *Alcohol Drugs and Driving* 9:7-28.

Lestina, Diane C., and Lund, Adrian K. (1992). Laboratory evaluation of two passive alcohol sensors. *Journal of Studies on Alcohol* 53:328-334.

Moscowitz, Herbert and Robinson, Christopher, D. 1987. Effects of low doses of alcohol on driving related skills: A review of the evidence. (Technical Report) DOT-HS-807-280. Washington, DC: National Highway Traffic Safety Administration.

Lion Laboratories Ltd. (1987). Lion Alcolmeter S-D2 Operating Instruction Manual. Barry, United Kingdom: Lion Laboratories Ltd.

SAS Institute, Inc. SAS/STAT Users Guide. Version 6, Fourth Edition. Cary, NC: SAS Institute, Inc., 1990.

Public Service Technologies, Inc. (1995). P.A.S. III Passive Alcohol Sensor Instruction Manual. Fredericksburg, VA.: Public Service Technologies Inc.

764.slf
April 19, 1996