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An In Vitro Study of the Accuracy and Precision of Breathalyzer® Models 900, 900A, and 1000

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ABSTRACT: Ninety Breathalyzer® instruments (Model 1000) and twenty instruments (Models 900, 900A) were studied using a protocol described by the Department of Transportation's "Standard for Devices to Measure Breath Alcohol." Although the mean of each of three concentrations tested (0.05, 0.10, and 0.15 g/210 L) compared favorably in both series, the standard deviation was consistently higher for the Model 1000 instruments. The Model 1000 instruments also produced a significant number of test results which exceeded the normally expected scientific deviation.

KEYWORDS: forensic science, breath-alcohol testing devices, protocols, Breathalyzer®

The Breathalyzer®, invented by Robert F. Borkenstein in 1954, has been the most popular and widely used of the current breath testing instruments. Since its development, the Breathalyzer and the scientific principle underlying its operation have been proven precise and accurate when properly used [*1-4*]. The Model 1000 Breathalyzer automates the sample collection and analysis, thereby reducing the possibility that the operator may influence the results of the test. The in vitro precision and accuracy of a single Breathalyzer Model 1000 was reported by Dubowski [*5*]. Additional preliminary testing was conducted by Altshull [*6*].

The State of Maryland undertook a project to replace the manually operated Model 900 and 900A Breathalyzer instruments with the automated, tamperproof Model 1000. Since the judiciary and law enforcement agencies in Maryland were already familiar with the Breathalyzer's operating principles and reputation, maintaining instrument continuity in the program update was a major consideration. Following a limited evaluation of several Model 1000 Breathalyzer instruments, 90 units were ordered to replace the manually operated Models 900 and 900A instruments currently in use.

A variety of malfunctions caused numerous instruments to be returned to the manufacturer for repairs; consequently, it was decided to conduct a broader systematic evaluation patterned after portions of the Department of Transportation's "Standard for Devices to Measure Breath Alcohol" (DOT protocol) [*7*] on all instruments received. A revised protocol has since been published [*8*]. Since the Model 1000 was to replace the Models 900 and 900A units, which had been established to be reliable and accurate, a similar evaluation was conducted on 20 randomly selected Model 900 and 900A instruments currently in field use.

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Materials and Methods

Instruments

Ninety Model 1000 Breathalyzer instruments were received previously checked and certified as suitable for testing by the Smith & Wesson Company. Twenty Model 900 and 900A Breathalyzer instruments were randomly selected from field use and were checked for chamber output, temperature, and light alignment before commencing the evaluation tests. No other adjustments were made to these units. Testing of the Model 1000 Breathalyzer instruments was conducted in the laboratory at the Maryland State Police Headquarters by experienced Breathalyzer maintenance technicians. Testing of the Models 900 and 900A Breathalyzer instruments was conducted at the field installation by an experienced chemist.

Preparation of Ethanol Simulator Solutions

A stock ethanol solution was prepared by diluting 77 mL of absolute ethanol with sufficient distilled water to make 1 L. The concentration of the solution was confirmed by head space gas chromatography using a Perkin-Elmer F-40 Multifract Gas Chromatograph with *n*-propanol as the internal standard.

Using this stock solution, ethanol solutions delivering vapor ethanol concentrations of 0.050, 0.100, and 0.150 g/210 L were prepared by diluting the stock solution with sufficient distilled water to make 500 mL (1 mL of stock solution for each 0.010-g/210-L concentration desired). The ethanol solutions were prepared in 4-L lots to minimize solution variability and their concentrations confirmed by head space gas chromatography using a Perkin-Elmer F-40 Multifract Gas Chromatograph with *n*-propanol as the internal standard.

Testing Protocol

The testing of the Model 1000 Breathalyzer instruments was conducted on three instruments sequentially. Ten tests at each target concentration were conducted on each instrument and the results recorded. To assure uniformity during the testing the following guidelines were established:

1. A 500-mL aliquot of the appropriate ethanol solution was placed in a clean, dry Smith & Wesson Mark II-A Simulator and allowed to achieve operational temperature (34° ± 0.2°C).
2. Before testing, a sample was delivered from the simulator and vented into the atmosphere. The simulator was allowed to stand with stirring and heating for at least 30 s to reestablish equilibrium. A sample from the simulator was then delivered sequentially into the three instruments being tested. (The first simulator sample to Instrument 1, the second sample to Instrument 2, the third sample to Instrument 3, the fourth sample to Instrument 1, the fifth sample to Instrument 2, and so forth).
3. A maximum of 35 samples was delivered from any 500-mL aliquot of each ethanol solution.
4. The number of tests conducted using a single Smith & Wesson Certified Breathalyzer Solution ampoule was as follows: At a 0.05-g/210-L ethanol concentration, five tests were conducted on each of two ampoules. At a 0.10-g/210-L ethanol concentration, four tests were conducted on the first ampoule, and three tests on each of the second and third ampoules. At a 0.15-g/210-L ethanol concentration, three tests were conducted on the first and second ampoules and two tests were conducted on the third and fourth ampoules.

Accuracy and Precision

The accuracy of the breath testing devices was determined by following the guidelines established in the DOT protocol. Essentially, the procedure requires evidential breath test

devices to measure the alcohol content of a vapor mixture with a systematic error of not more than ±10% at an ethanol vapor concentration of 0.050 g/210 L, and ±5% at ethanol vapor concentrations of 0.100 and 0.150 g/210 L.

The method used to determine the precision of the breath testing devices once again followed the guidelines established in the DOT protocol. This required that breath test devices shall measure the alcohol content of an ethanol vapor mixture with an average standard deviation (SD) for the three concentrations of not more than 0.004 concentration units (g/210 L).

Results and Discussion

Ninety Breathalyzer 1000 Instruments were received by the State of Maryland. Preliminary testing of a few of these production line instruments indicated that their performance did not meet the expectations predicted by an earlier evaluation of several company-loaned demonstration units. Therefore, all 90 instruments were subjected to more comprehensive testing as described by the DOT protocol.

During the testing, 19 (21%) of the Model 1000 Breathalyzer instruments experienced mechanical malfunctions which prevented the instrument from collecting and analyzing the sample and displaying and printing the results of the 30 sequential tests properly; a majority of these failures were printer malfunctions. Of the instruments that experienced no mechanical malfunctions, 15 (17%) could not meet the precision and accuracy requirements. Failure to perform as expected caused 34 (38%) of the 90 instruments to be returned to the manufacturer. Twenty-seven instruments were received back from the manufacturer after repairs had been completed and were retested; ten (37%) of these instruments again failed to perform as expected with six of the instruments experiencing the identical problems exhibited during their initial testing.

Of the 90 Model 1000 instruments available, 86 were tested (4 were not able to complete the testing sequence on their second attempt and were not included in the study) with 59 tested 1 time and 27 tested twice for a total of 113 tests. Twenty randomly selected Models 900 and 900A field instruments were also tested. The results are shown in Table 1. The mean values for each of the three test concentrations compared favorably. The SD on the other hand, was consistently higher for the Model 1000 instruments. It is noted that both sets of data are within the allowed tolerance set by the DOT protocol (SD less than 0.004 g/210 L). Yet the range of tests was wider for the Model 1000 than for Models 900 and 900A. This may be explained in part by the greater number of tests, but one wonders whether the wider deviation noted with the Model 1000 was excessive.

To evaluate the wide ranges of tests experienced with the Model 1000 Breathalyzer instruments as shown in Table 1, individual test results were tabulated to ascertain how many test results exceeded an acceptability criterion set at the maximum SD allowed by the DOT protocol (0.004 g/210 L). Tests within the 0.004-g/210-L criterion would represent a high degree of acceptability. Normal statistical evaluation would indicate that at twice the criterion, not more than 5% of results should deviate and at three times the criterion not more than 1% of results should deviate. Table 2 shows the number and percent of tests at each of the three concentrations which exceed by two or three times the criterion. The percent of test results with the Model 1000 instrument was greater than with Models 900 and 900A in each case. At 0.05 g/210 L, there were zero deviations for Models 900 and 900A while the Model 1000 showed 1.9 and 0.6% for two and three times the criterion, respectively. Although the Model 1000 deviation exceeded Models 900 and 900A, the results were within the acceptable limits. At 0.100 g/210 L, the Model 1000 showed 6.3 and 2.3% for two and three times the criterion, respectively, while Models 900 and 900A showed 2.5 and 0% in each respective group. At a 0.150-g/210-L concentration, the Model 1000 showed 15.5 and 4.7% for two and three times the criterion, respectively, while Models 900 and 900A showed 3.5 and 0% in each respective group. At both 0.100- and 0.150-g/210-L concentrations, Breathalyzer Models 900 and 900A

TABLE 1—*In vitro evaluation of the Breathalyzer Model 1000 and Models 900 and 900A.*[a]

	Vapor Ethanol Concentration, g/210 L									
	0.050			0.100			0.150			
Target Value	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD	Avg. SD
Models 9000, 900A ($N = 20$)	0.050	0.046–0.058	0.0018	0.100	0.096–0.110	0.0025	0.150	0.141–0.161	0.0029	0.0024
Model 1000[b] ($N = 113$)	0.050	0.043–0.064	0.0028	0.100	0.092–0.148	0.0034	0.151	0.125–0.246	0.0046	0.0037

[a]The mean and SD reported in each respective column are derived from the means obtained from each individual series of 10 tests.
[b]Of 90 instruments evaluated, 4 could not be tested and 27 were tested twice.

TABLE 2—*Test results in Breathalyzer instruments exceeding an established criterion.*[a]

	Vapor Ethanol Concentration, g/210 L											
	0.050			0.100			0.150			Totals		
Target Value	*N*	>2 times[b]	>3 times[b]	*N*	>2 times	>3 times	*N*	>2 times	>3 times	*N*	>2 times	>3 times
Models 900, 900A	200	0	0	200	5 (2.5%)	0	200	7 (3.5%)	0	600	12 (2%)	0
Model 1000	1130	22 (1.9%)	7 (0.6%)	1130	71 (6.3%)	26 (2.3%)	1130	175 (15.5%)	53 (4.7%)	3390	268 (7.9%)	86 (2.5%)

[a]An acceptability criterion of 0.004-g/210-L equivalent to the maximum SD allowed by the DOT standard was used.
[b]Two or three times the acceptability criterion.

met the expected tolerances while the Model 1000 exceeded these tolerances. As a composite, Models 900 and 900A showed acceptable deviations of 2 and 0% at two and three times the criterion, respectively, while the Model 1000 showed excessive deviations of 7.9 and 2.5% in each respective group. This evidence confirmed the early observation that the Model 1000 Breathalyzer displayed a tendency to produce "spikes" or apparently excessive deviant test results. Aberrant results increased with increasing vapor alcohol concentration; however, these are most significant at concentrations in the transition ranges (0.08%, 0.10%) which define legal intoxication.

Experience in the State of Maryland indicates that every instrument to be introduced into routine use should be tested. Although demonstration and other field units may perform satisfactorily, there is no assurance that any manufacturer can consistently provide a production instrument whose results can be expected to warrant the trust of the judiciary and the public. The DOT standards should be considered to assist in such evaluations [*7,8*]. It is clear that the Model 1000 Breathalyzer exhibited a tendency toward more variable results and overall was inferior to Models 900 and 900A. More recent improvements or modifications to the Model 1000 may have improved its performance. Although the theory of operation may be sound, and limited federal testing may have approved the instrument, it is recommended that all new instruments be evaluated in the field by the local agencies who expect to use them.

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