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Infrared Quantitative Evidential Breath-Alcohol Analyzers: In Vitro Accuracy and Precision Studies

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ABSTRACT: The in vitro accuracy and precision of four infrared breath-alcohol analyzers, the Alcotest 7010, BAC Verifier, Intoxilyzer 5000, and Intoximeter 3000, were studied with a protocol adapted from portions of the U.S. Department of Transportation's (DOT) "Standard for Devices to Measure Breath Alcohol." Statistical evaluation of these studies indicated that all instruments met or exceeded the performance requirements modified from the U.S. DOT Standard for quantitative evidential breath-alcohol analyzers.

KEYWORDS: toxicology, breath-alcohol testing devices, protocols

With the advent of advanced infrared (IR) breath-alcohol analyzer and microprocessor technology, IR absorption spectrometry has become a major technique in the quantitative analysis of breath for alcohol content. The IR absorption technique uses an IR light source that is directed through the sample cell, reflected across a series of mirrors, and onto a special IR detector which is operating at a wavelength (3.3 to 3.5 μm) sensitive to ethyl alcohol. Ethyl alcohol present in the sample cell absorbs IR energy, and therefore, quantitation is possible by measuring a decrease in the intensity of the IR source at the detector. The electronic signal from the detector is converted (A/D) and the concentration of the ethyl alcohol in the vapor is displayed digitally.

The Department of Transportation (DOT) generally tests submitted instruments utilizing a procedure described in the "Standard for Devices to Measure Breath Alcohol" (DOT Protocol) [*1,2*]. Satisfactory instruments are then placed on an approved products list which permits their purchase with federal funds. If federal funds are not involved, police agencies are not restricted by this list. Although it is desirable that any instrument proposed for use by any agency be tested extensively by that agency, such practices vary considerably and many rely on the evaluations of others presented in the literature. To that end, we have conducted in vitro evaluations on four IR instruments in our laboratory using a modified DOT protocol. Although this report is not exhaustive and is limited to the evaluation of a production model of each particular instrument, we present comparison data on the most recently DOT approved quantitative IR breath-alcohol analyzers.

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Materials and Methods

Instruments

The following instruments were evaluated: (1) Alcotest 7010 (National Draeger Corp., Pittsburgh, PA), (2) BAC Verifier (Verax Systems, Inc., Fairport, NY), (3) Intoxilyzer 5000 (CMI, Inc./Federal Signal Corp., Chicago, IL), and (4) Intoximeter 3000 (Intoximeters, Inc., St. Louis, MO). All instruments were U.S. production models with the exception of the Alcotest 7010 which was assembled in West Germany.

Smith and Wesson Mark IIA breath alcohol simulators (Smith and Wesson Company, G.O.E.C., Pittsburgh, PA) were operated at 34 ± 0.2°C in tandem arrangement to deliver various concentrations of vapor ethyl alcohol.

A Perkin-Elmer F-45 head space analyzer (Perkin-Elmer Corp., Norwalk, CT) was used for all gas chromatographic analyses.

Preparation of Ethyl Alcohol Solutions

A stock ethyl alcohol solution (60.50 g/L) was prepared by diluting 308 mL of absolute ethyl alcohol (U.S.P. 200 Proof; Warner Graham Co., Cockeysville, MD) with sufficient distilled water to constitute 4 L. The concentration of the stock solution was confirmed by dichromate oxidation and head space gas chromatography.

Using the stock solution, ethyl alcohol simulator solutions were prepared in 4-L quantities; simulator solutions at 34°C containing 0.605, 1.210, 1.815, 3.025, and 4.840 g of ethyl alcohol/L yield vapor ethyl alcohol effluents of 0.050, 0.100, 0.150, 0.250, and 0.400 g/210 L. Therefore, for each 0.010 g/210 L of ethyl alcohol concentration desired, 8.0 mL of stock solution was used. The concentrations of the working simulator solutions were confirmed by head space gas chromatography.

Testing Protocol

The following protocol (adapted from the U.S. Department of Transportation's "Standard for Devices to Measure Breath Alcohol") was used to evaluate each instrument:

1. A 500-mL aliquot of the appropriate ethyl alcohol solution was placed in each Mark IIA Simulator and allowed to reach operational temperature.
2. Before the commencement of testing, the simulators were vented into the atmosphere. A sample was then delivered into the instrument.
3. Twenty "blank" analyses were performed on each instrument.
4. Twenty consecutive tests were performed at each concentration on each instrument. The following concentrations were used on the BAC Verifier, Intoxilyzer 5000, and Intoximeter 3000: 0.050, 0.100, 0.150, 0.250, and 0.400 g/210 L. Since the range of operation on the Alcotest 7010 is 0.000 to 0.300 g/210 L, the following concentrations were used: 0.050, 0.100, 0.150, and 0.250 g/210 L.
5. A maximum of 25 samples was delivered from any set of simulators.

Accuracy and Precision

Accuracy and precision were determined according to the testing protocol. As an indication of precision, standard deviation among repeated measurements of a single concentration was calculated. In accordance with the DOT standard, breath-alcohol analyzers must measure the alcohol content of vapor mixtures with a combined average standard deviation of no more than 0.0042 g/210 L at 0.050, 0.101, and 0.151 g/210 L. Additionally, as a measure of accuracy, evidential breath devices must measure the alcohol content of a vapor mixture with a systematic

error of no more than ±5% or 0.005 g/210 L at 0.050, 0.101, and 0.151 g/210 L, whichever is greater.

Results

Results of in vitro studies on the Alcotest 7010, BAC Verifier, Intoxilyzer 5000, and Intoximeter 3000 are presented in Tables 1 to 4, respectively. In addition to standard deviation and systematic error, mean, range, and coefficient of variation are indicated.

No erroneous digital responses were observed during any test series, including the analysis of vapor from "blank" simulator effluents. All test sequences were free from interruption and all instruments operated without failure.

TABLE 1—*Vapor alcohol analyses: accuracy and precision of the Alcotest 7010.*

	Target Concentration, g/210 L			
	0.050	0.100	0.150	0.250
Number	20	20	20	20
Mean, g/210 L	0.048	0.099	0.153	0.251
Standard deviation, g/210 L	0.0011	0.0008	0.0011	0.0015
Systematic error, %	−4.0	−1.0	+2.0	+0.4
Coefficient of variation, %	2.3	0.8	0.7	0.6
Range, g/210 L	0.047–0.050	0.098–0.100	0.151–0.154	0.249–0.254

TABLE 2—*Vapor alcohol analyses: accuracy and precision of the BAC Verifier.*

	Target Concentration, g/210 L				
	0.050	0.100	0.150	0.250	0.400
Number	20	20	20	20	20
Mean, g/210 L	0.049	0.100	0.150	0.249	0.393
Standard deviation, g/210 L	0.0009	0.0013	0.0012	0.0011	0.0019
Systematic error, %	−2.0	0.0	0.0	−0.4	+1.8
Coefficient of variation, %	1.8	1.3	0.8	0.4	0.5
Range, g/210 L	0.047–0.051	0.098–0.102	0.148–0.152	0.247–0.251	0.391–0.397

TABLE 3—*Vapor alcohol analyses: accuracy and precision of the Intoxilyzer 5000.*

	Target Concentration, g/210 L				
	0.050	0.100	0.150	0.250	0.400
Number	20	20	20	20	20
Mean, g/210 L	0.048	0.100	0.152	0.252	0.397
Standard deviation, g/210 L	0.0012	0.0016	0.0015	0.0025	0.0026
Systematic error, %	−4.0	0.0	+1.3	+0.8	−0.8
Coefficient of variation, %	2.5	1.6	1.0	1.0	0.7
Range, g/210 L	0.046–0.050	0.098–0.103	0.149–0.153	0.247–0.256	0.393–0.403

TABLE 4—*Vapor alcohol analyses: accuracy and precision of the Intoximeter 3000.*

	Target Concentration, g/210 L				
	0.050	0.100	0.150	0.250	0.400
Number	20	20	20	20	20
Mean, g/210 L	0.052	0.103	0.151	0.250	0.393
Standard deviation, g/210 L	0.0007	0.0008	0.0008	0.0020	0.0016
Systematic error, %	+4.0	+3.0	+0.7	0.0	−1.8
Coefficient of variation, %	1.3	0.8	0.5	0.8	0.4
Range, g/210 L	0.051-0.053	0.101-0.104	0.149-0.152	0.247-0.253	0.391-0.396

Conclusion

Statistical analyses indicate that the Alcotest 7010, BAC Verifier, Intoxilyzer 5000, and Intoximeter 3000 met or exceeded the performance requirements adapted from the U.S. Department of Transportation Standard for quantitative breath-alcohol analyzers. Additionally, the infrared absorption technique utilized by these breath-alcohol analyzers yielded results similar to those reported in a previous validation study of the Breathalyzer® Models 900 and 900A [*3*].

Note that all studies described were limited to accuracy and precision. Although, response to acetone by these infrared breath-alcohol analyzers was not addressed in this study, this question was addressed in two recently published reports [*4,5*]. The results of this study indicate that these instruments are suitable for consideration; however, more extensive evaluation examining multiple units of the same instrument and other factors is suggested to insure the validity and success of the instrument in a breath-alcohol testing program.

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