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Nitromethane K-9 Detection Limit

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Introduction

The Bureau of Alcohol, Tobacco and Firearms (ATF) trains canine/handler teams to detect explosives for government and other agencies worldwide. After completing the training program the teams are tested on an array containing explosives and numerous other samples designed to distract a canine. Passing this test results in a team's certification.

These teams can be considered as 'detection instruments' freshly calibrated just before leaving the 'factory'. Using these teams to examine special experimental arrays immediately following certification can lead to a better understanding of a canine's detection capabilities.

Forty-one of these 'detection instruments' were used in four test series with arrays containing dilute nitromethane-in-water solutions. (The canines had been trained on the amount of nitromethane vapor in equilibrium with the undiluted liquid explosive.) By diluting liquid nitromethane with water, the amount of explosive vapor can be reduced many orders of magnitude to test the lower limit of the canine's nitromethane vapor detection response. The results are presented in this paper.

Test Description

Most samples were placed in the standard ATF test wheel geometry show in Figure 1. Two-ounce ointment tins with holes punched in the lids contained either diluted nitromethane, actual explosives or distracters. A number of empty tins were also used in the array. The tins were placed in quart cans that were then placed inside gallon cans attached to the wheel.

Individual gallon cans positioned in a linear array were used for one series of tests. On two series of tests several individual gallon cans containing samples were positioned after the last wheel in the array.

Series I with 12 canine/handler teams was run on September 18, 2000 using eight wheels. Twenty-four tins were empty and 8 contained nitromethane diluted with de-ionized water. The tins' lids had 15 holes ~1.5 mm in diameter.

Series II with 12 canine/handler teams was run on November 27, 2000 using a linear array of 40 cans. Seven tins were empty. Six tins contained distilled water. Six tins contained distracters and 6 tins contained explosives. Fifteen tins contained nitromethane diluted with distilled water. The tins' lids had 13 holes ~1.0 mm in diameter.



Figure 1. ATF test wheel

Five canine/handler teams were used in Series III screening experiments on March 7, 2001. Four wheels and 2 individual cans were used. Three tins contained tap water and 1 tin contained a distracter. Six tins contained explosive and 8 tins contained nitromethane diluted with tap water. The tins' lids had 13 holes ~1.0 mm in diameter.

Series IV with 12 canine/handler teams was run on May 8, 2001 using seven wheels and three individual cans. Eight tins were empty and 6 contained tap water. Four contained explosives and 13 contained nitromethane diluted with tap water. The tins' lids had 15 holes ~1.0 mm in diameter.

The standard ATF scoring procedure was used to record the canine's response. Teams were allowed to circle a wheel twice at the handler's discretion. Sitting indicated a positive reaction to the sample. On correctly identifying an explosive or nitromethane-containing sample the canine was given a food reward.



Figure 2. Positive

Test Results

There were 503 tests of nitromethane and diluted nitromethane samples. The results are presented in Table 1. (Scorer sheets are summarized in Appendix A.)

Table 1. Detection results for water-diluted nitromethane solutions

Nitromethane Vapor Pressure Range (microns)	Number of Dog/Handler Teams	Total Tests	Total Positive Responses
4×10^4 (<i>pure nitromethane</i>)	12 on 5/8/01 tests	17	16 (94%)
1×10^3 to 1×10^2	12 on 9/18/00 tests 12 on 11/27/00 tests	44	40 (91%)
3×10^1 to 3×10^0	12 on 9/18/00 tests 12 on 11/27/00 tests	36	26 (72%)
3×10^{-1} to 1×10^{-2}	12 on 9/18/00 tests 12 on 11/27/00 tests	48	41 (85%)
3×10^{-3} to 1×10^{-4}	12 on 9/18/00 tests 12 on 11/27/00 tests	42	37 (88%)
1×10^{-5} to 1×10^{-6}	12 on 11/27/00 tests 5 on 3/7/01 tests	79	68 (86%)
3×10^{-7} to 1×10^{-8}	5 on 3/7/01 tests 12 on 5/8/01 tests	96	44 (46%)
3×10^{-9} to 1×10^{-9}	5 on 3/7/01 tests 12 on 5/8/01 tests	41	28 (68%)
3×10^{-11} to 3×10^{-13}	12 on 5/8/01 tests	68	44 (65%)

Observations

Some of the most significant knowledge gained in these series of experiments centered on the unique difficulties in the testing of detection canines. Among the observations:

- Canines are at all times thinking, learning creatures. It is difficult to design the “learning factor” out of a test protocol.
- The canine must be trained and familiar in the test methodology; the mechanics of the test.

- The levels of the substance to be detected experimentally must also be included in the canines normal training. A dog not trained to detect very low levels may not do so in an experiment. The dog must be trained at the levels it will be expected to work.
- The presentation order of low levels of a target substance affects the test results. If a relatively high level of a target odor is presented first on a wheel together with a low level of the same substance the dog may selectively alert to the higher level only.

Conclusion

The probability of detecting nitromethane remained high until the vapor pressure fell below $\sim 1 \times 10^{-6}$ microns. This would place detection limits in the parts-per-trillion range in the headspace above the sample tin. There are indications that some of the canines were detecting much lower concentrations of nitromethane vapor, but the evidence from these experiments is inconclusive. Further work lies ahead.

Appendix A

Four separate test arrays using ointment tins with precisely punched lids were used in the nitromethane tests. The scorer results for each of the teams are presented below. Sample positions are indicated either by wheel and arm numbers (W1 A1) or can #. Y indicates a positive response, Yw indicates a weak positive response and N indicates no response.

NM Vapor Pressure (microns)	Date	Location	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	% Y
37,000	5/8/01	W1 A1*	Y Y	Y Y	N Y	Y	Y	Y Y	Y Y	Y	Y	Y	Y	Y	94%
1000	9/18/00	W8 A1**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
322	9/18/00	W7 A4**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
109	11/27/00	Can 1*	Y	N	N	Yw	Y	N	Y						57%
106	9/18/00	W5 A3**	Y	Y	Y	Y	Y	Y	Y	Y	N Y	Y	Y	Y	91%
26	9/18/00	W2 A2**	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	92%
11	11/27/00	Can 3*	Y	N	N	N	N	Y	Y	N	Y	N			40%
2.6	9/18/00	W1 A3**	Y	Y	Y	Y	Y	Y	N Y	Y	N	Y	N Y	Y	79%
0.26	9/18/00	W3 A1**	Y	Y	Y	Y	Y	Y	N Y	Y	Y	Y	Y	Y	92%
0.11	11/27/00	Can 22*	N	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y	67%
0.026	9/18/00	W6 A3**	Y	Y	Y	Y	Y	Y	Y	Y	N Y	Y	Y	Y	92%
0.011	11/27/00	Can 12*	Y	Y	Y	Y	Y	N	Y						86%
0.011	11/27/00	Can 14*	Y	Y	N										33%
0.0026	9/18/00	W4 A3**	Y	Y	Y	Y	Y	Y	N Y	Y	Y	Y	Y	Y	92%
0.0011	11/27/00	Can 20*	Y	Y	Y	N									75%
0.0011	11/27/00	Can 25*	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	92%
0.00011	11/27/00	Can 27*	Y	Y	Y	Y	Y	N	N	Y	Y	Y			80%
0.00011	11/27/00	Can 29*	Y	Y	Y										100%

* lid with 13 1-mm diameter holes

** lid with 15 >1-mm diameter holes

Water-Diluted Nitromethane Tests (cont.)

NM Vapor Pressure (microns)	Date	Location	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	% Y
0.000011	11/27/00	Can 18*	Y		N	Y	Y	Y	Y	Y					86%
0.000011	11/27/00	Can 32*	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	92%
0.000011	11/27/00	Can 36*	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	75%
0.0000011	11/27/00	Can 9*	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	83%
0.0000011	11/27/00	Can 17*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
0.0000011	11/27/00	Can 30*	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	92%
0.0000011	3/7/01	W3 A4*	N Y		Y Y	Y	N Y								71%
0.0000011	3/7/01	Can 2*	Y	Y	Y	Y	N								80%
0.00000034	5/8/01	W6 A2*	Y	Y	N	N	Y	Y	Y	N	N	Y	N	Y	8%
0.00000034	5/8/01	W7 A2*	Y	Y N	N Y	Y	N	N N	N	N	N	Y	N	N	33%
0.00000034	5/8/01	Can 3*	Y	Y	N	Y	N	Y	Y	Y	Y	Y	N	Y	75%
0.00000011	3/7/01	W2 A4*	N N	N	Y Y	Y	N N								38%
0.00000011	3/7/01	W3 A3*	N N		N N	N	N N								0%
0.000000034	5/8/01	W5 A2*	Y	N Y	N Y	Y		Y	Y	N	N	N	N	N	46%
0.000000034	5/8/01	W6 A2*	Y	Y	N Y	Y	Y	N	Y	N	Y	N	N	Y	62%
0.000000011	3/7/01	W1 A4*	N Y	N N	Y Y	Y	Y Y								56%
0.000000011	3/7/01	W2 A3*	N Y	N	N	N	N N								14%
0.0000000034	5/8/01	W4 A1*	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	83%
0.0000000034	5/8/01	W4 A4*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	92%
0.0000000034	5/8/01	Can 2*	Y	Y	N	Y									75%
0.0000000011	3/7/01	W1 A3*	N N	N N	N	N	N N								0%
0.0000000011	3/7/01	Can 1*	Y	N	Y	Y	Y								80%

* lid with 13 1-mm diameter holes

Water-Diluted Nitromethane Tests (cont.)

NM Vapor Pressure (microns)	Date	Location	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	% Y
0.0000000000034	5/8/01	W3 A2*	Y	Y	Y	Y	Y	N Y	Y	N	Y	Y	N	Y	77%
0.0000000000034	5/8/01	W3 A4*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
0.00000000000034	5/8/01	W2 A1*	Y	N N	N Y	N Y	N Y	Y	Y	N	N Y	N	Y	N	47%
0.00000000000034	5/8/01	W2 A3*	Y	N Y	N Y	Y	N N	N	Y	N	N Y	N	N	Y	44%
0.00000000000034	5/8/01	Can 1*	Y	Y	Y	Y	N	Y	Y	N	Y	Y	N	Y	75%

* lid with 13 1-mm diameter holes

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