US ARMY RDECOM®

U.S. Army Research, Development and Engineering Command

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Suppressor Blowback Measurement
NDIA Armament Systems Forum
28 April 2016

Adam Jacob – U.S. Army ARDEC

Purpose

Develop a Method to Measure and Quantify Blowback From Small Arms Systems

- Blowback – Refers to the tendency of a small arms system to blow gases back through the chamber and toward the Operator after the bolt opens
- Although there has been work done in the area, there is no standard or accepted method to measure this phenomena with respect to the gases experienced by the Operator in a repeatable manner

Unsuppressed M249

Suppressed M249

*Photos courtesy of AAI/Textron.

Background

Unsuppressed M249

Suppressed M249

- Many Operators report increased blowback when a suppressor is added to a small arms system – we also have some qualitative laboratory evidence of this
- Different suppressor designs result in different amounts of blowback
- Why is this a problem?
  - Operational impact
- How is it currently measured and assessed?
- Why do we need to measure it?
  - Comparison of suppressors
  - Predict operational impact
  - Generation of requirements

*Photos courtesy of AAI/Textron.

Malcolm Baldrige National Quality Award 2007 Award Recipient

Small Arms Toxic Gas Testing – Toxins

Toxins in Small Arms Exhaust Gases

- Ammonia (NH_3)
- Carbon Dioxide (CO_2)
- Carbon Monoxide (CO)
- Hydrogen Cyanide (HCN)
- Methane (CH_4)
- Nitric Oxide (NO)
- Nitrogen Dioxide (NO_2)
- Sulfur Dioxide (SO_2)

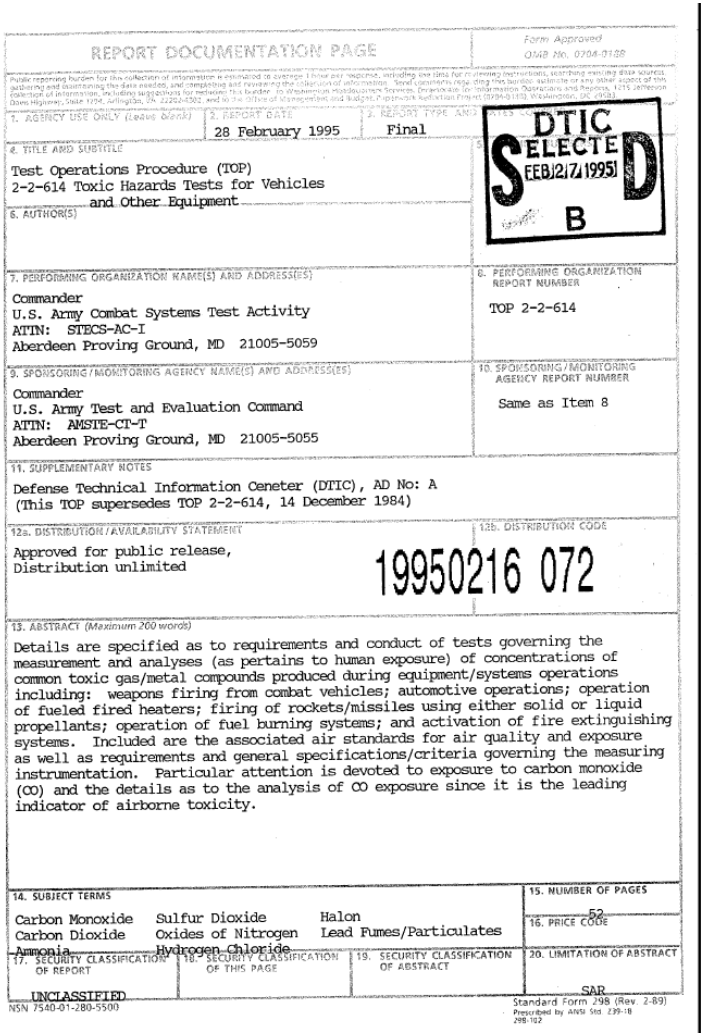
Small Arms Toxic Gas Testing – Toxins

Toxins in Small Arms Exhaust Gases

- Ammonia (NH_3)
- Carbon Dioxide (CO_2)
- Carbon Monoxide (CO)
- Hydrogen Cyanide (HCN)
- Methane (CH_4)
- Nitric Oxide (NO)
- Nitrogen Dioxide (NO_2)
- Sulfur Dioxide (SO_2)

Current Small Arms Toxic Gas Testing

- TOP 2-2-614
  - Purpose of Current Testing – Health Hazard Assessments (HHA)
  - Section 4.2 Weapons Systems Tests
    - "Open air toxic fumes testing… not normally conducted…"
    - Typically done inside the vehicle from which they may be fired (combat vehicle, etc.) in order to create a realistic scenario
- Other Methods IAW TOP 2-2-614
  - Military Operations in Urban Terrain (MOUT) situations
  - This testing is still aimed at Health and Safety, rather than operational impact



REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE: 28 February 1995 | 3. REPORT TYPE AND DATES COVERED: Final

DTIC ELECTE FEB 27 1995 B

4. TITLE AND SUBTITLE: Test Operations Procedure (TOP) 2-2-614 Toxic Hazards Tests for Vehicles and Other Equipment

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES): Commander, U.S. Army Combat Systems Test Activity, ATTN: STECS-AC-I, Aberdeen Proving Ground, MD 21005-5059

8. PERFORMING ORGANIZATION REPORT NUMBER: TOP 2-2-614

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES): Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-CT-T, Aberdeen Proving Ground, MD 21005-5055

10. SPONSORING/MONITORING AGENCY REPORT NUMBER: Same as Item 8

11. SUPPLEMENTARY NOTES: Defense Technical Information Ceneter (DTIC), AD No: A (This TOP supersedes TOP 2-2-614, 14 December 1984)

12a. DISTRIBUTION/AVAILABILITY STATEMENT: Approved for public release, Distribution unlimited

12b. DISTRIBUTION CODE: 19950216 072

13. ABSTRACT (Maximum 200 words)

Details are specified as to requirements and conduct of tests governing the measurement and analyses (as pertains to human exposure) of concentrations of common toxic gas/metal compounds produced during equipment/systems operations including: weapons firing from combat vehicles; automotive operations; operation of fueled fired heaters; firing of rockets/missiles using either solid or liquid propellants; operation of fuel burning systems; and activation of fire extinguishing systems. Included are the associated air standards for air quality and exposure as well as requirements and general specifications/criteria governing the measuring instrumentation. Particular attention is devoted to exposure to carbon monoxide (CO) and the details as to the analysis of CO exposure since it is the leading indicator of airborne toxicity.

14. SUBJECT TERMS: Carbon Monoxide, Carbon Dioxide, Ammonia, Sulfur Dioxide, Oxides of Nitrogen, Hydrogen Chloride, Halon, Lead Fumes/Particulates

15. NUMBER OF PAGES: 52

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT: UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE

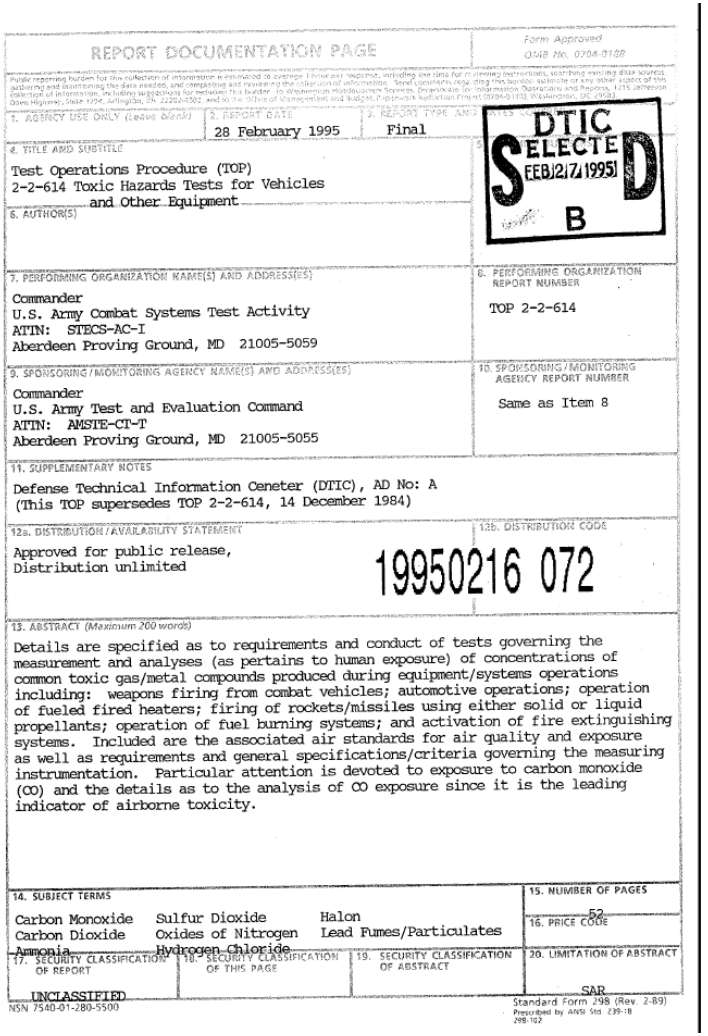
19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT: SAR

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. 239-18 298-102

Current Small Arms Toxic Gas Testing

- TOP 2-2-614
  - Purpose of Current Testing – Health Hazard Assessments (HHA)
  - Section 4.2 Weapons Systems Tests
    - "Open air toxic fumes testing… not normally conducted…"
    - Typically done inside the vehicle from which they may be fired (combat vehicle, etc.) in order to create a realistic scenario
- Other Methods IAW TOP 2-2-614
  - Military Operations in Urban Terrain (MOUT) situations
  - This testing is still aimed at Health and Safety, rather than operational impact



REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE: 28 February 1995 | 3. REPORT TYPE AND DATES COVERED: Final

DTIC ELECTE FEB 27 1995 B

4. TITLE AND SUBTITLE
Test Operations Procedure (TOP) 2-2-614 Toxic Hazards Tests for Vehicles and Other Equipment

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Commander
U.S. Army Combat Systems Test Activity
ATTN: STECS-AC-I
Aberdeen Proving Ground, MD 21005-5059

8. PERFORMING ORGANIZATION REPORT NUMBER
TOP 2-2-614

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Commander
U.S. Army Test and Evaluation Command
ATTN: AMSTE-CT-T
Aberdeen Proving Ground, MD 21005-5055

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Same as Item 8

11. SUPPLEMENTARY NOTES
Defense Technical Information Ceneter (DTIC), AD No: A
(This TOP supersedes TOP 2-2-614, 14 December 1984)

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release,
Distribution unlimited

12b. DISTRIBUTION CODE
19950216 072

13. ABSTRACT (Maximum 200 words)
Details are specified as to requirements and conduct of tests governing the measurement and analyses (as pertains to human exposure) of concentrations of common toxic gas/metal compounds produced during equipment/systems operations including: weapons firing from combat vehicles; automotive operations; operation of fueled fired heaters; firing of rockets/missiles using either solid or liquid propellants; operation of fuel burning systems; and activation of fire extinguishing systems. Included are the associated air standards for air quality and exposure as well as requirements and general specifications/criteria governing the measuring instrumentation. Particular attention is devoted to exposure to carbon monoxide (CO) and the details as to the analysis of CO exposure since it is the leading indicator of airborne toxicity.

14. SUBJECT TERMS
Carbon Monoxide, Carbon Dioxide, Ammonia, Sulfur Dioxide, Oxides of Nitrogen, Hydrogen Chloride, Halon, Lead Fumes/Particulates

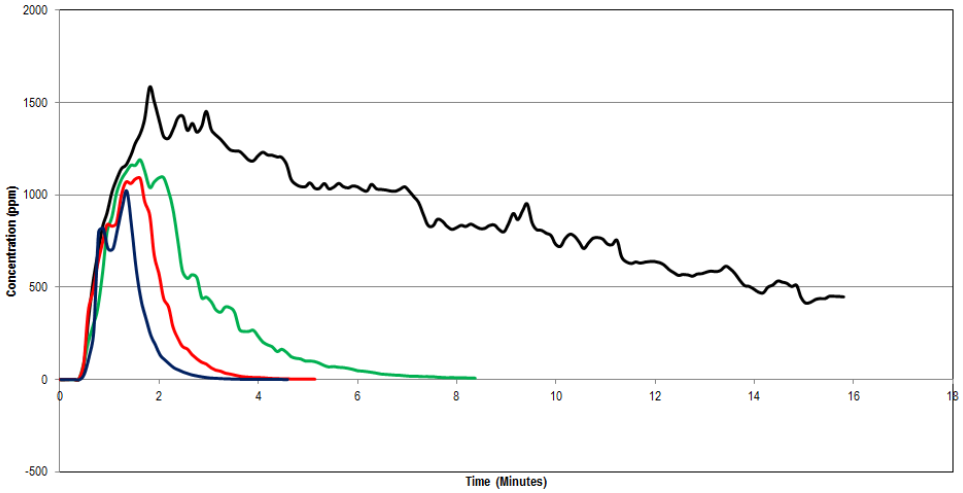
15. NUMBER OF PAGES: 52
16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT: UNCLASSIFIED
18. SECURITY CLASSIFICATION OF THIS PAGE
19. SECURITY CLASSIFICATION OF ABSTRACT
20. LIMITATION OF ABSTRACT: SAR

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. 239-18 298-102

Malcolm Baldrige National Quality Award 2007 Award Recipient

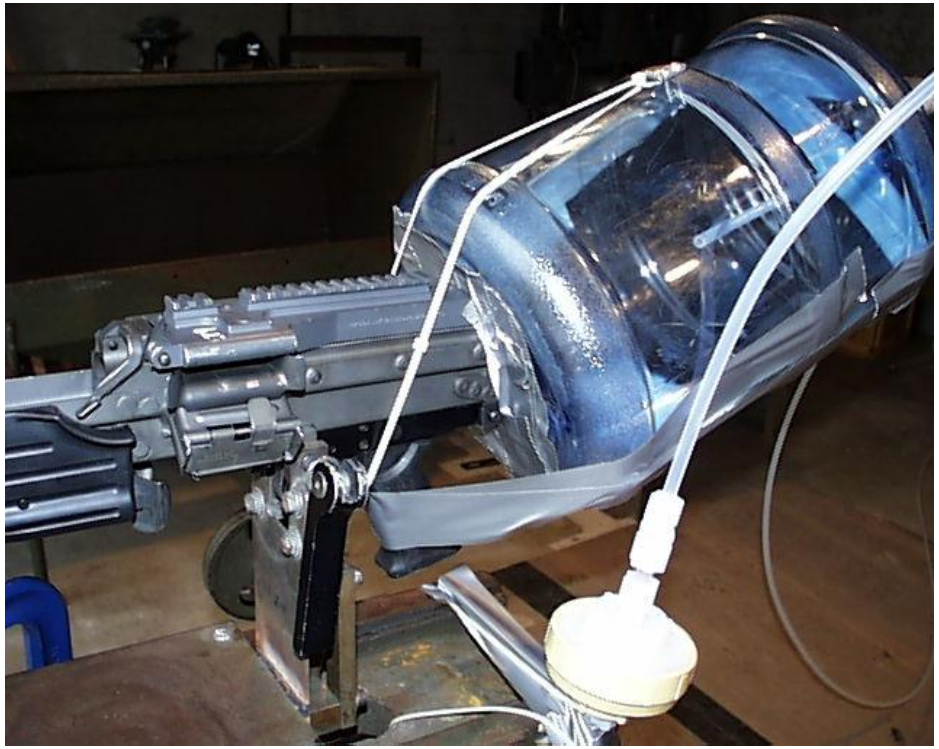
U.S. Army MOUT Chamber



*Photos/Data courtesy of Aberdeen Test Center (ATC), Aberdeen Proving Ground, MD.

US ARMY RDECOM

2005 U.S. Army Blowback Test

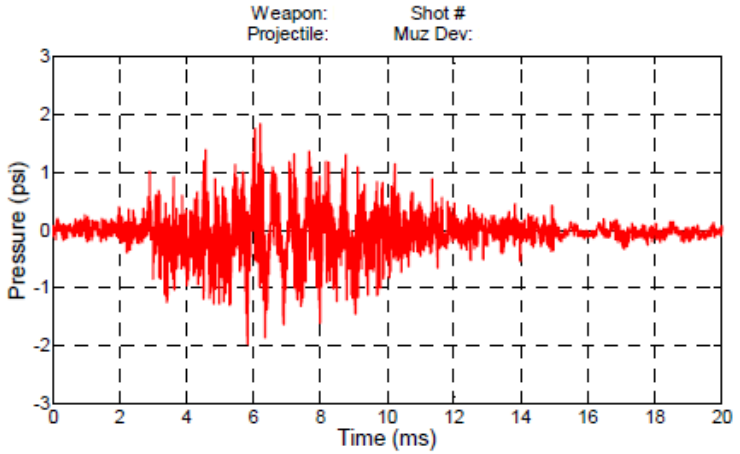


*Photos from 2005 ATC report, “Comparison of Toxic Gas Results for the M249 SAW, (Squad Automatic Weapon) Weapons Firing Testing Using Various Suppressors”.

Malcolm Baldrige National Quality Award 2007 Award Recipient

Optimization of Signature and Sound Suppression (OSASS) Developmental Method

Test Setup



Sample Data

*Photo and plot courtesy of Dan Cler, U.S. Army ARDEC.

Malcolm Baldrige National Quality Award 2007 Award Recipient

Path Forward

Where do we go from here?

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	28 February 1995	Final

DTIC ELECTE FEB 27 1995 B

4. TITLE AND SUBTITLE
Test Operations Procedure (TOP)
2-2-614 Toxic Hazards Tests for Vehicles and Other Equipment

5. FUNDING NUMBERS

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Commander
U.S. Army Combat Systems Test Activity
ATIN: STECS-AC-I
Aberdeen Proving Ground, MD 21005-5059

8. PERFORMING ORGANIZATION REPORT NUMBER
TOP 2-2-614

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Commander
U.S. Army Test and Evaluation Command
ATIN: AMSTE-CT-T
Aberdeen Proving Ground, MD 21005-5055

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Same as Item 8

11. SUPPLEMENTARY NOTES
Defense Technical Information Ceneter (DTIC), AD No: A
(This TOP supersedes TOP 2-2-614, 14 December 1984)

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release,
Distribution unlimited

12b. DISTRIBUTION CODE

19950216 072

13. ABSTRACT (Maximum 200 words)
Details are specified as to requirements and conduct of tests governing the measurement and analyses (as pertains to human exposure) of concentrations of common toxic gas/metal compounds produced during equipment/systems operations including: weapons firing from combat vehicles; automotive operations; operat of fueled fired heaters; firing of rockets/missiles using either solid or liqu propellants; operation of fuel burning systems; and activation of fire extingu systems. Included are the associated air standards for air quality and exposu as well as requirements and general specifications/criteria governing the meas instrumentation. Particular attention is devoted to exposure to carbon monox (CO) and the details as to the analysis of CO exposure since it is the leadin indicator of airborne toxicity.

14. SUBJECT TERMS
Carbon Monoxide, Carbon Dioxide, Ammonia, Sulfur Dioxide, Oxides of Nitrogen, Hydrogen Chloride, Halon, Lead Fumes/Particulates

15. NUMBER OF P
52
16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF
UNCLASSIFIED			SAR

NSN 7540-01-280-5500

Standard Form 298 (R
Prescribed by ANSI Std. Z39
298-102

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.
UNCLASSIFIED

Challenges for Blowback Testing

- Gas concentrations are most important
- Need to look specifically at the added blowback resultant of a suppressor (or, potentially, any design feature)
- Must address the gases that are blown back to the User's face (versus all blown back)
- Must be repeatable
  - Eliminate wind, etc.
  - Common set up
- Must represent an operational scenario
- Test setup must be feasible for all potential users
- Must be affordable for all potential users

Path Forward

1. Preliminary proof of concept test at Army Research Lab (ARL) Aerodynamics Range (18-22 April, 2016)
   - Test blowback using a wide variety of different methods
   - Multiple weapons and suppressors from high blowback, to low

2. Analyze data
   - Assess the ability of each method to measure blowback differences at the Operator's location
   - Determine which methods have the best results, both in ability to measure differences from system to system, as well as repeatability of measurements
   - Overall cost of method will also be considered

3. Write standardized test method

4. Validate standardized method in live fire test

Methods Assessed

Handheld Gas Analyzer – MultiRAE Pro

- CO, NH3, HCN
- Tested as both a chamber assessment, and a real-time assessment at the Operator's face
- Test full weapon, as well as chamber gases only

Pros

- Less expensive
- More readily available
- Easy to use

Cons

- Slow Reaction Time
- Does not analyze all gases, must pick and choose

Methods Assessed

High Sensitivity Microphones at Various Locations (Similar to OSASS)

- Highly sensitive piezo electric microphones located at Operator's face
- Measures pressure wave which can be compared from system to system

Pros

- Concept proven in OSASS
- Able to measure small differences in pressure

Cons

- Difficult to shield muzzle blast from blowback
- Pressures may be too low at Operator location

http://www.pcb.com/products.aspx?m=106B

Methods Assessed

Shadowgraph / High Speed Video

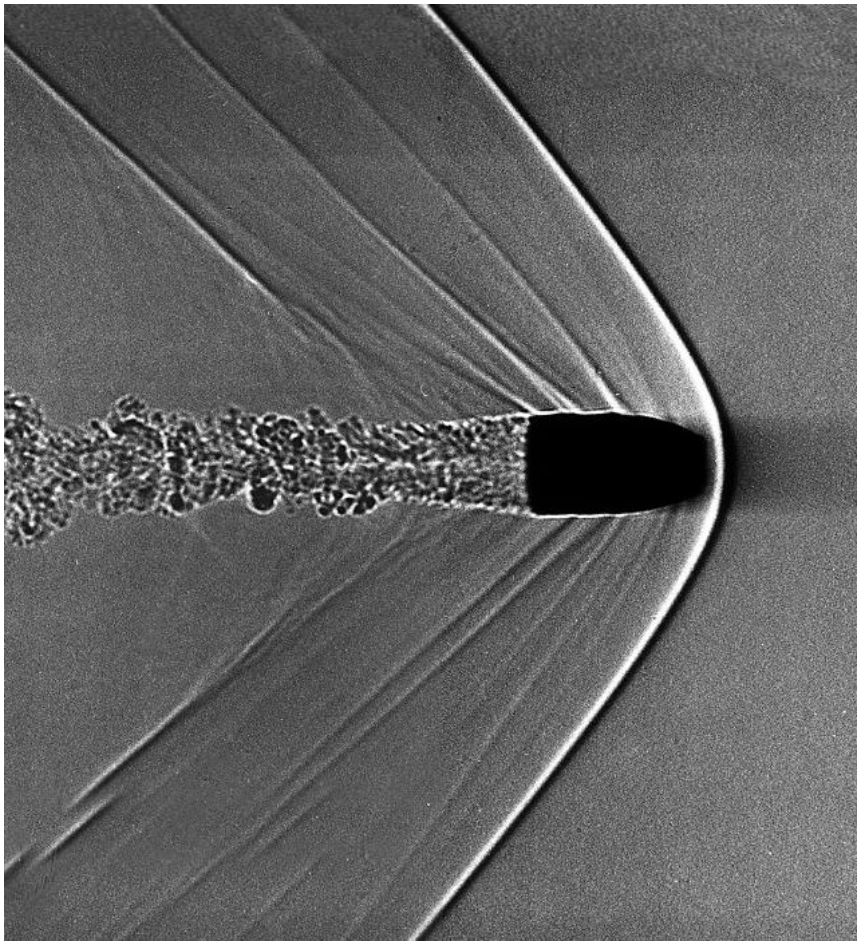
- Often used to look at projectile aerodynamics
- Provides qualitative data regarding pressure waves throughout the air

Pros

- Proven technology
- High likelihood of providing good qualitative data

Cons

- May be difficult to quantify data
- May be cost prohibitive for contractors, NATO partners



https://en.wikipedia.org/wiki/File:Supersonic_Bullet_Shadowgraph.jpg

Methods Assessed

Planar Doppler Velocimetry (PDV)

- Uses laser/Doppler methods to track particle velocity through a plane
- Particles in propellant gas could potentially be tracked

Pros

- High probability of providing accurate and repeatable measurements of velocities at the Operator location

Cons

- Not readily available
- Could be cost prohibitive to industry and/or NATO partners
- Doesn't tell you anything about gas concentrations, just velocities

Methods Assessed

Bag Collection Method

- Vacuum pump is used to pull air into a collection bag at a given flow rate
- Collected air is sent to a laboratory for analysis

Pros

- Input can be positioned at Operator face location
- Adjustable flow rate
- Laboratory can assess for wide variety of gases
- Inexpensive and portable

Cons

- Very flow rate dependent
- Parameters must be applicable to all weapons
- Repeatability could be an issue

http://www.restek.com/catalog/view/11097

Summary

1. The addition of a suppressor to a small arms system has the potential to increase the amount of toxic gases blown back toward the User during weapon operation.
2. These gases can result in an operational impact by causing a User to experience burning/watering eyes, difficulty breathing, and potential burns which could cause him to momentarily and immediately become ineffective in firing the weapon.
3. Although there has been work done in the area, there is no standardized method to measure and assess blowback.
4. This is currently being addressed through the development of a measurement methodology that is intended to eventually be both a NATO and MIL standard.

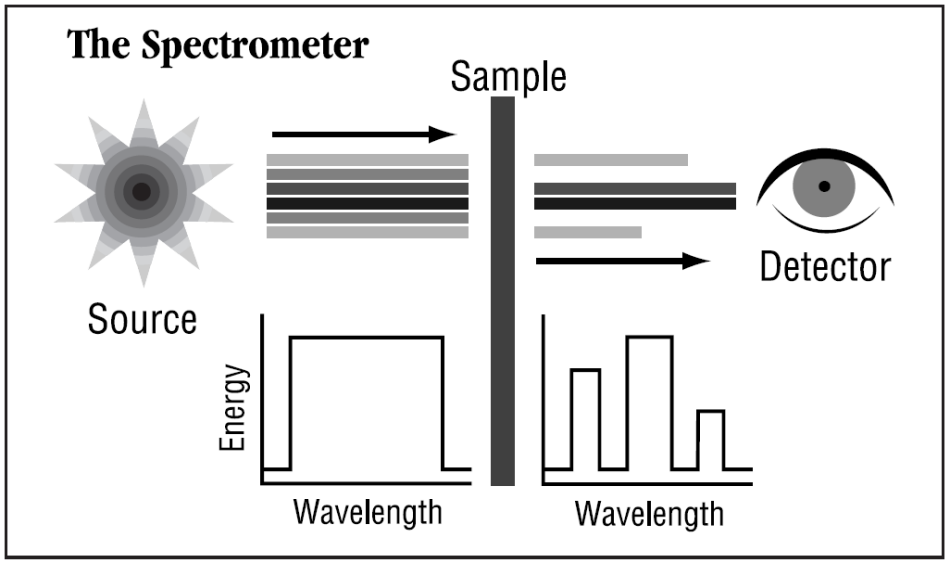
Questions/Discussion

Backup Slides

Equipment Overview – FTIR

How Does It Work?

- An infrared (IR) radiation beam is generated and passed through an Interferometer
- Interferometer manipulates the beam (this is done to enable all frequencies to be measured simultaneously)
- The manipulated beam is passed through a sample, where some IR is absorbed, and some passes through (transmitted)
- Detector measures the signal
- Resulting spectrum represents the total absorption and transmission for all frequencies
- Fourier Transformation is used to calculate individual frequencies



http://mmrc.caltech.edu/FTIR/FTIRintro.pdf

Open Air vs. Chamber

Open Air Testing

Advantages	Limitations
Simulates specific operational conditions	Introduces variables such as wind, etc., that will affect results
Can be compared to exposure limits to analyze impact to health or function	Sampling too slow to catch “peaks” – may result in artificially low readings
Air inlet can be placed directly at the position of interest (User’s face)	Not a “worst case” condition

Chamber Testing

Advantages	Limitations
Ensures that all gases of interest are captured	Not operationally relevant unless the chamber size and ventilation reflect specific operational firing scenarios
Eliminates issue of slower sampling rates	Generates artificially high concentrations
Good for comparing emission data for different weapon systems, ammunition, or configurations of weapon or ammunition	Cannot be compared to exposure limits to analyze impact to health or function, unless the conditions reflect specific scenario that you are interested in
A chamber would be a worse case than open air	Cannot zero in on specific location (User’s face)

Summary of Test Attributes

Current Testing (TOP 2-2-614)	Proposed Blowback Testing
Measures toxic gas concentrations	Measures toxic gas concentrations
Measures total gas concentrations resultant from firing a weapon system (including muzzle gases)	Measures concentrations only of the gas blown back at User (muzzle gases not included)
Does not measure temperature or pressure	Could measure temperature and pressure at selected areas of interest
Purpose is to quantify toxic gases in order to assess health risk for HHA	Purpose is to quantify only the gases that are blown back toward the User to assess risk of immediate operational impact
Largely independent of weapon design, and mostly dependent on combustion products of ammunition	Very dependent on weapon and suppressor design due to increased backpressure
	Quantify the increase in blowback in a weapon system as a result of the addition of a suppressor, perhaps as a percentage
	Assess risk of operational impact due to blowback (this is not required, but would be ideal)